In Two Sections

Electrical Engineering

July
1931

Section
Two

This Section Contains

the Annual Reports of the Eighteen Technical Committees of the Institute

Published by
American Institute
of Electrical Engineers, New York

Annual Technical Committee Reports To the Board of Directors

In accordance with Section 82 of the A. I. E. E. By-laws, the Technical Committees of the Institute have prepared the following reports for presentation at the Summer Convention.

In addition to a brief outline of its own activities, each committee gives a resume of the progress of the art within its field, so that collectively, these reports constitute an authoritative history of the developments in electrical engineering during the past year.

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Automatic Stations

ANNUAL REPORT OF THE COMMITTEE ON AUTOMATIC STATIONS*

CONSIDERABLE data on many phases of the automatic station art have been collected by subcommittees and are made part of this report, which is treated under headings as follows:

Technical Papers	Wire Designations
Standards	Research
New Subjects	Operating Data
Unfinished Business	Telemetering
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Technical Papers

The following papers are being presented under the auspices of the Committee at the Summer Convention, Asheville, N. C., 1931.

1. *A-C. Supervisory Control System.* By Othmar K. Marti.
2. *Supervisory Control for A-C. Electrified Railroads.* By C. P. West and H. C. Griffith.
3. *Automatic Combustion Control.* By C. H. Sanderson and E. B. Ricketts.
4. *Operating Experience with Automatic Stations.* By Garland Stamper and F. F. Ambuhl.
5. *Three Years' Operating Experience with Miniature Switchboard Supervisory Automatic Control.* By R. M. Stanley.

Standards

Standards No. 26, Automatic Stations, has again been reviewed by the Committee. Recommendations for revisions in the list of device function numbers and in the table of minimum protection for power apparatus have been forwarded to the Standards Committee.

New Subjects

Automatic combustion control and automatic alternating current networks have been studied this year by the Committee. A paper on Automatic Combustion Control, covering this subject extensively for the first time, is being presented at the annual convention.

Unfinished Business

Of the items listed last year, preliminary reports on Fire Protection, Load Dispatching and Wire Designations have been completed and are contained herein.

The following topics have been under consideration but no final reports have been rendered:

1. Economical Construction.
2. Noise Mitigation.
3. Automatic Alternating Current Networks.
4. General Telemetering.

Subcommittee Reports

To the Subcommittees contributing the following reports generous acknowledgment is given. It is desired to make known that the efforts so prominently reflected in these reports are appreciated in full measure.

Fire Protection

Contributed by I. E. Moultrop and D. W. Taylor.

The methods of accomplishing suitable fire protection from the points of view of safety to personnel, safety to apparatus, and continuity of service have long been the subject of discussion and investigation by the electrical engineering profession. The size and importance of electrical installations make adequate fire protection a matter of utmost importance. The increasing use of automatically operated stations brings into prominence the special problems confronted by the designers of these usually unattended installations, which may in some instances be so far removed from the nearest aid in case of fire as to make automatic fire protection a corollary of automatic operation. It is the purpose of this report to point out some of these special problems.

When the subject of fire protection is considered, it is well to make a study of the causes of fires to obtain a perspective of the various elements entering into the problem. Consideration can then be given to design, and apparatus and material specifications, which will eliminate as much as possible the trouble at the source. Studies may be made to determine if oil circuit breakers have the necessary interrupting capacity; if all load carrying apparatus has the proper thermal capacity; if relay protection can be provided to clear short circuits before damage may occur, etc. Many apparatus characteristics, such as oil circuit breaker interrupting capacities, have been proven by tests so that greater reliability may be placed in their performance than was the case a few years ago.

Means to limit the fire to the vicinity of its source and prevent involving other apparatus in an attended or unattended substation, may take any one or more of

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three forms, *viz.*: automatic means of fire detection and alarm; structural means of fire isolation; and means of fire fighting, either manual or automatic.

Automatic means of fire detection, as at present commercially developed, take the form of thermocouples and fusible links to convert the heat energy released by combustion into electrical energy, or of the more complicated apparatus working as a detector of the resultant smoke. Although these automatic means of fire detection have occasionally been installed in attended stations merely to alarm the operators, the recent mechanical improvement of the devices commercially obtainable for this service has resulted in considerable application of such devices in unattended stations to give alarm at some central attended installation and/or to operate fire-fighting equipment adjacent to the source of trouble. Unattended stations whose operations are reported to a central office through some means of supervisory control are particularly adapted for the installation of an alarm system between the station and the central office.

The second form of fire protection, structural means of fire isolation, is applied for the same reason and with equal effect in both attended and unattended stations. The large quantity of oil used in modern electrical apparatus makes fire isolation an important problem both indoors and outdoors. Generally, if possible, it is desirable to install large oil-filled apparatus outdoors and eliminate as much indoor oil-filled apparatus as is possible.

Indoors, apparatus of different types and different degrees of importance may be placed in different rooms, with fire doors between, either normally closed or closed by gravity upon the release of a fusible link. Some companies go so far as to install oil-immersed transformers in one room, large oil circuit breakers in a long narrow room with windows only at the ends, and oil-immersed voltage regulators in still another room; only the smaller breakers being installed in the same room with the switchboard and major bus structure. In connection with the location of windows, many stations are so arranged that any outdoor apparatus liable to catch fire, if installed adjacent to the building wall, are located at considerable distance from the nearest opening into the building. Another precaution taken as a means of indoor fire isolation comprises the use of cell doors and other trim made of treated wood or other fireproofed material. Current transformers, on which the relay protection is dependent, have been sometimes placed in separate compartments so they will not be involved in an arc from other equipment before they have actuated the tripping relays. Proper grounding of apparatus often lessens the chance of stray currents damaging other equipment during a short circuit. Elimination, as much as possible, of unprotected apparatus connected to the main bus is often desirable. Protection of apparatus, such as bus potential transformers, by means of resistance and fuses and careful isolation of bus arresters, should be considered.

Outdoors, transformers may be installed with fire walls between banks of two or three units or, if larger and more important transformers, between individual units. One company has recently adopted the policy, on large outdoor transformers, of eliminating the column-type oil gage from the conservator and of installing fuse-releasing gravity-closing valves on all connections between conservator and main tank. It is intended by this policy to prevent the spreading of possible transformer fires by the release of the large quantity of oil contained in the conservator, as sometimes happens through the cracking of the gage glass on the occurrence of fire in the immediately adjacent transformer and through the feeding out of burning oil from a rupture in the cover of a faulty transformer.

Both indoors and outdoors, fire isolation may be augmented by the installation of pits and drainage systems properly disposed with respect to oil-immersed transformers and regulators and oil circuit breakers.

The third form of fire protection, means of fighting the actual fire, divides naturally between the use of liquids and the use of gases. The most obvious liquid for this purpose is water, which is often piped to the end-bells of large rotating machinery and may be used elsewhere in connection with one of the commercial sprinkler systems; there is, however, considerable question as to the efficacy of water as a means of fighting oil fires. Other liquids take the form of special preparations, often generated on the premises at the time of fire, either by the mixture of two liquids or of water and a powder. Gaseous means are limited commercially to the use of carbon dioxide, which is heavier than oxygen and serves to smother the fire when applied in sufficient concentration; it is therefore particularly suitable in confined spaces where liquid might damage the apparatus and/or where the gases emanating from some of the commercial liquid preparations would be obnoxious. The efficacy of all these fire-fighting fluids may be considerably increased by the installation of permanent piping, designed to permit the direction of the fluid at the most advantageous point in case of fire. Whether or not the valves of this piping should be automatically operated depends not only upon the importance of the installation and the liability of a large fire, but also upon the proximity to a central attended installation and the attendant costs of automatic equipment for fire alarm as compared with the costs of automatic equipment for fire fighting in the unattended station.

It is believed that the art of fire protection is developing so rapidly, particularly in connection with unattended automatic stations, that no standards should be promulgated at this time by the American Institute of Electrical Engineers or others. It is thought that only by giving comparatively free rein can it be assured that progress will continue to be made in accordance with the best economic dictates.

The attached Appendix A is a preliminary attempt to classify for further investigation or study, I. the causes

of fires, II. the spreading of fires, III. preventive measures, and IV. the extinguishing of fires.

Appendix A

I. Causes of Fires. II. Spreading of Fires. III. Preventive Measures. IV. Extinguishing of Fires.

I—Causes of Fires

A. Faulty Design
1. Insufficient spacing.
2. No allowance for temperature changes.
3. Reduced clearances from distortion due to short circuits.
4. Conductors or equipment improperly or insecurely supported.
5. Weakness of mechanical structure or supports.
6. Insufficient provision against heaving by frost, entrance of rain, or accumulation of sleet.
7. Cannon construction (by cannon construction is meant the arrangement of barriers or compartments in such a manner as to direct an arc outward into other equipment or into operating aisles).

B. Faulty Equipment
1. Improper design.
2. Poor material.
3. Defective materials or parts.
4. Insufficient insulation, spacing of parts, strength or thermal capacity.
5. Improper assembly.
6. Improper and insufficient testing.
7. Unnoticed failures as a result of testing.

C. Improper Application of Equipment
1. Wrong material—moisture absorbing, subject to chemical change.
2. Wrong apparatus—type, size, rating.

D. Aging of Apparatus and Material
1. Deterioration of insulating material on conductors, supports, windings.
2. Corrosion of metals from action of air, moisture, electrolysis.
3. Effect of moisture, gases and corona in hastening deterioration.

E. Static Stresses
1. Causing destruction of insulation.
2. Collecting conducting material.

F. Magnetic Stresses
1. Mechanical movement.
2. Collecting conducting material.

G. Surges or Lightning
1. Atmospheric conditions.
2. Switching operations.
3. Improper grounding.

H. Arcs (other than flashovers)
1. Switching operations.
2. Contactors.
3. Commutators.

I. Exceeded Ratings
1. Exceeded current rating, overload.
2. Overvoltage.
3. Exceeded temperature rating.
4. Exceeded time.

J. Errors in Operation

K. Failure of Apparatus Containing Oil
(This includes oil circuit breakers, oil switches, transformers, potheads, etc.)
1. Insufficient amount of oil.
2. Surplus amount of oil.
3. Slopping of oil (mufflers, discharges).
4. Dripping of oil on other apparatus.
5. Lowering of oil level due to leaks, syphoning or intense cold.
6. Freezing of oil.
7. Carbonization of oil.
8. Presence of moisture.
9. Explosions due to arcs following short circuits.
10. Poor contact.
11. Puncture of bushing.
12. Internal corona discharges.
13. Internal earth fault.
14. Internal short circuit.
15. Phase interruptions due to mechanical failures.
16. Short-circuited laminations.
(Note: See other sections for failure of apparatus in general).

L. Exposure to External Attack
1. Animals—birds, rats, nests, etc.
2. Foreign material thrown on equipment—stones, kite strings, airplanes.

M. Dirty Apparatus
1. Dirt from coal piles, or adjacent industries.
2. Boring action of metallic slivers.
3. Causing reduced radiation.
4. Causing flashovers.

N. Spontaneous Combustion
1. Oily waste or rags
2. Coal.

O. Friction
1. Lack of lubrication.
2. Improper alinement.
3. Dirt.

P. Condensation
1. Unheated conditions.
2. Temperature changes in conduits.
3. Unventilated conditions.
4. Wrong materials.

Q. Heating Equipment and Piping
1. Failure of electrical heaters.
2. Defective flues.
3. Explosions of oil burners.
4. Escaping steam or water from pipes.
5. Broken fuel lines.

R. Carelessness
1. Improper tagging or operation (disconnects, etc.).
2. Cigarettes, matches.

S. Atmospheric Conditions
1. Flashovers due to fogs, especially salt water fogs.
2. Sleet or wind.

T. Exterior Fires
1. Adjacent buildings.
2. Grass and forest fires.

II—Spreading of Fires

A. Inflammable Material in Apparatus
1. Insulating material in conductors, such as rubber and varnished cambric.
2. Insulating supports or braces, such as wood.
3. Oil or inflammable compounds.

B. Inflammable Material in Construction
1. Wooden buildings, compartments, or structures.
2. Forms used during construction.

C. Insufficient Segregation
1. Insufficient barriers, compartments, cells or rooms.
2. Insufficient spacing between types or classes of apparatus.
3. Improper grouping of equipment, wiring, etc.
4. Improper drainage of oil, etc.

D. Poor Housekeeping
1. Rubbish during construction
2. Accumulation of rubbish in operation.
3. Storage of inflammable material.

E. Fanning Action of Ventilating Equipment.

F. Lack of fire Extinguishing Apparatus.

G. Failure to Announce Start of Fire, Smoke or Heat.

III—Preventive Measures

A. Use of fire-proof or fire-resisting material in construction.

B. Elimination of oil so far as possible.

C. Keeping premises and apparatus clean.

D. Segregation of apparatus.

E. Correct design or application.

F. Constant expert supervision.

G. Careful inspection before and during installation.

H. Periodic testing.

IV—Extinguishing of Fires

A. Detection.

B. Alarms.

C. Accessibility.

D. Automatic fire extinguishers—classification and suitability of each type.

E. Hand-operated extinguishers—classification and suitability of each type.

F. Drainage of burning oil.

Wire Designations

Contributed by O. J. Rotty and M. E. Reagan.

The development of a uniform scheme of wire designations for station control wiring has been given some study with the idea that if a satisfactory scheme could be devised it should be offered for standardization.

The general use of such a scheme would produce uniform marking of control wiring at all stations regardless of whether the panels were wired by different manufacturers or by the user himself. This seems desirable for many reasons. The engineer laying out a new station or an extension to an old one would have to be familiar with only one scheme of wire designations and if the apparatus for a particular station was supplied by a number of manufacturers the wire designations would be alike for all the apparatus, resulting in simplification of interconnecting wires and common circuits. These points are also of importance to the construction or installation men, to the testing men, maintenance men, trouble shooters, etc.

At present there are many schemes in use, with each manufacturer and many utilities and engineering organizations having their own schemes all of which are different although some may have certain features in common. There seem to be many reasons why each scheme is preferred by its sponsor and why other schemes are objectionable. However, it is felt that a scheme can be devised which will fulfill practically all requirements and overcome the more important objections. The standard scheme must be of a general nature and must be applicable to all kinds of stations; *viz.*, railway, Edison, mining, hydro, a-c. distribution, and even steam plants.

There is a number of points in the designation of wires on which there is fairly general agreement. These are briefly as follows: 1. The scheme should be simple, easily understood and applied and with few special cases or exceptions; 2. it should be flexible so as to permit of additions or changes to the control without completely revising the existing designations; 3. it should provide the "tie-in" with or reference between the actual wire and the diagrams (either the wiring diagram, the schematic diagram, or both); 4. the wire designations should appear on the schematic (or elementary) diagram.

It also seems desirable that certain other ideas be worked into the standard scheme, which are briefly as follows: 1. The wire designation should be made up of as few digits as possible; 2. it should not be a complicated combination of letters and numbers; 3. it should preferably have some significance as to the apparatus or panel the wire connects to, although this appears to be difficult to devise and very likely an arbitrary scheme will be finally adopted; 4. operating and control buses and circuits of the nature of buses should be included in the standard scheme.

This subject has been taken up by this committee only recently and the time has been insufficient for the development of a finished scheme. However, it is felt that the work should be continued by the succeeding committee.

Several closely allied subjects have presented themselves for investigation but lack of time has prevented work upon them. They are: 1 Wire group or conduit designations or numbers, and 2, wire color codes. It is felt that these should also be given some study with a view to suggesting standards for them.

Research

Contributed by M. E. Reagan.

Research items to be studied and followed by the committee are divided under four main divisions. One object of investigation is to assemble data on operation while another object is to establish the trend of automatic expansion in operation. For instance, in the use of vacuum gas filled tubes in power and control systems, it will be the function of this committee to carefully record the various applications and keep experience charts showing the growth of usefulness and their performance.

The four general classifications are as follows:

I. Automatic Control of Rotating Machines (including mercury arc rectifiers).
   a. Synchronous converters.
   b. Motor-generator sets.
   c. Mercury-arc rectifiers.
   d. Hydro-electric generators.
   e. Frequency-changers.
   f. Synchronous condensers.
   g. Balancer sets.
   h. Battery chargers
      1. Automatic end cell switches.

II. Automatic Control of Static Machines.
   a. A-c. transformer substations.
   b. Periodic reclosing feeders.
   c. Static condensers.

III. Network Protectors.

IV. Supervisory Control.
   a. Terminal apparatus.
   b. Channels.
      1. Fused lines.
      2. Private.
      3. Carrier, etc.

Suggested Items.
   a. Curve of total installations by years.
   b. Curve of total kva. by years.
   c. Curve of per cent automatic to manual installation by years.
   d. Curve showing rehabilitation of old units for automatic service.
   e. Curve showing per cent availability by years.
   f. Data on primary causes of outages, such as
      1. Line trouble.
      2. Main apparatus trouble.
      3. Control trouble.
      4. Due to testers or maintenance man.
   g. Performance data on fuses in control circuits.
   h. Ventilation as it affects "sweating" of apparatus.
   i. General field testing of equipment expand last year's report.
   j. Data on vacuum tube applications of all types in control work.

Telemetering in Connection with Load Dispatching

Contributed by A. M. Garrett and J. J. Samson.

In order that electrical systems, particularly those of the public utility and traction companies, function with the highest degree of service standard and efficiency, it is necessary that the control of certain system operations be centralized.

Such operating knowledge and duties as restoration of the service to normal during or following a case of system trouble; the interchange of energy between systems or parts of the same system; switching in and out of service of generating station or substation units in accordance with load demands; the load quantities

existing in different parts of the system; the maintenance of proper voltage, frequency, temperature of equipment; adjusting the system to take care of construction work in connection with system extensions, maintenance and repairs, are some of the functions that must come under the guidance of this group.

The majority of these functions is under the control of the load dispatcher or system operator who depends upon his knowledge of the operating condition of the system through the forces which actually operate it. This information comes to him in the nature of a periodic check, generally by telephone.

In recent years as the system developed through growth and expansion, and in some instances through combination, the problems associated with the handling of these systems become more involved, so that the need for quicker and more accurate information as to the operating status of the system became apparent. In order to handle the situation intelligently, a continuous record or "running account" so to speak was needed instead of a periodic sampling of conditions. To meet these requirements telemetering or remote indication equipment has been developed and placed in service in many systems in this country in the past five years. To take care of these problems under the old method would mean quite a material increase in the load dispatchers' force.

Telemetering is a means of transmitting to a central control point over a communicating circuit or special conductors, information necessary for the operation of the equipment, station or system. This may be electrical quantities (volts, amperes, watts, power factor), temperature, position of breakers, regulators, or any other information that it may be desired to obtain from the system.

It consists essentially of a transmitter at the remote end connected to the equipment from which information is desired, a receiver at the control end and the connecting circuit. The quantity of energy to be measured or position of equipment to be indicated is converted to a voltage and current (suitable for telephone cable) whose value is proportional and is transmitted to the receiver which is calibrated to record the information.

With a view to determining the trend of telemetering devices and methods, the committee decided that a survey in the form of a questionnaire should be made of those companies now operating this class of equipment.

The questionnaire covered the following points:

1. What of the following do you use telemetering for?
   Totalizing load.
   Current and voltage conditions.
   Temperature of equipment.
   Position of switch gear.
   Tap changer and regulator positions.
   Uses other than above.
2. State briefly the type of system and the principles of operation.
3. What channels are used?
   Telephone lines.
   Transmission lines.
   Special conductors.
   State approximate distances of transmission.
4. Is this system of aid in load dispatching?
   In what manner?
5. What criticism do you have of telemetering?
6. What, in your opinion, is the trend of development?

The term "load dispatching" is understood to cover broadly the function of load control and switching operation which is dependent upon telemetering information.

This survey has just been completed and a total of 35 companies canvassed. The following information has been compiled:

Under uses or application we found approximately 40 per cent of the companies use the equipment for determination of current and voltage conditions, while 22 per cent of the installations were for totalizing load and 18 per cent were for position indication of equipment.

Under types used, there seems to be a general use of direct current either in the form of balanced current or rectified current.

As the connecting circuit between the remote end and the receiving end, about 30 per cent used active telephone circuits, while the remaining 60 per cent used special conductors. The distance of transmission varies from 500 feet to 15 miles with no special average.

In answer to the direct question of whether the system was an aid in load dispatching, 60 per cent stated that it was, while the rest of the replies gave no opinion or indicated lack of experience due to the short time the equipment had been in service.

In reply to the inquiry on criticism of the equipment, the survey showed little or no adverse expression. One point emphasized was the lack of high speed response with accuracy comparable to the usual line of switchboard indicating instruments. There is a tendency where high speed is desired to sacrifice somewhat the matter of accuracy. Another criticism was on the cost basis, the installed cost of the equipment running into "considerable money." Especially is this true where special conductors are required over long transmitting distances.

Improvements toward simplification of the present complicated equipment, as means to greater reliability, was offered as one criticism.

On trend of development, practically all replies indicated a favorable reaction to future development, especially where extension to the system was in prospect. This applies particularly to the situation where interconnection is concerned. One reply mentioned there would be no future development for telemetering in this company as the type of distribution was being changed to an a-c. network whereby the substation would be eliminated.

In general, it can be stated that telemetering has established itself, and with extension of load control and switching operations made necessary through an increase in the size of systems, in interconnection between systems, and constantly increasing number of unattended stations, telemetering is proving a distinct aid in the solution of those problems of handling and operating an electric system.

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Communication

ANNUAL REPORT OF THE COMMITTEE ON COMMUNICATION*

IN accordance with the usual practise, this committee submits herewith a brief review of the developments during 1930 in electrical communication.

Telephone Service Improvements

Telephone service was improved during the year by the application of new developments and methods and improved maintenance. The average time to complete toll calls was lowered by 12 seconds to an average of one minute. Improved maintenance methods have reduced the frequency of troubles affecting subscribers' lines so that a trouble now occurs on the average but once in 22 months, a reduction in trouble frequency of about 11 per cent as compared with 1929.

Steady advancement in the quality of speech transmission was accomplished. On the longer haul toll business, unsatisfactory transmission conditions were experienced on only 1.5 per cent of the messages, compared with 1.7 per cent in 1929. One of the important factors contributing to this improvement was the institution of a more effective method for controlling the amplification of speech on toll calls involving two or more long circuits. An improved general plan for the design and rearrangement of plant to handle calls between remote points not connected by direct circuits was adopted. Under this plan, the number of intermediate switches is minimized with a consequent improvement in speed, accuracy, directness of routing, and transmission. A paper describing this plan, by Mr. H. S. Osborne, was presented at the 1930 Summer Convention. (A. I. E. E. Trans., October 1930.)

Subscriber's Equipment and Services

During 1930 the number of hand telephone sets in service increased to approximately 2,000,000 as against about 1,000,000 at the beginning of the year. The development of a type of hand set which would meet the electric and acoustic requirements of telephone practise in this country has involved the solution of difficult technical problems. These problems have been concerned primarily with the suppression of singing, for which the hand set has a tendency because of the rigid connection of the transmitter and receiver, and with the efficient operation of the transmitter in a wide range of angular positions. These difficulties have been successfully overcome through the application of a large amount of scientific work in the design of the hand set handle, the transmitting and receiving elements, and the electrical circuit connecting them. These achievements have made it possible to use the hand set without any sacrifice in performance as compared with the desk stand set.

For subscribers requiring a large number of attendants to take messages or orders, there has been made available an automatic call distributing arrangement associated with a simple type of attendant's position, whereby calls are immediately connected to idle attendants or, if none are available, are held and subsequently connected in the order in which they arrived.

A new type of private branch exchange suitable for larger residences and business offices of moderate size was made available during the year. No operator or attendant is required. Calls may be originated, answered, and transferred from any of the telephones. Intercommunicating calls are made by means of the dial. Complete privacy for both outside and intercommunicating connections is provided.

While arrangements have been available for some time for private branch exchanges whereby a number of telephones could be connected together simultaneously in a conference connection, these arrangements have been extended during the past year so as to enable the interconnection of a larger number of stations and to include more than one trunk circuit out of the private branch exchange.

Central Office Systems and Apparatus

During 1930 there was an increase of about 1,000,000 dial stations, bringing the total to approximately 5,565,000, or more than one-fourth of the total number of stations in this country. Besides the conversion to dial of additional portions of large cities, increasing use has been made of dial equipment in small communities where services requiring the assistance of operators can economically be handled from near-by centers.

Further extensions have been made in the mechanical tandem facilities used primarily for service between the larger areas and neighboring suburban points. Arrangements are now in service for automatically inserting voice repeaters when required on calls between

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the more distant points. Facilities are also included for completing calls to a variety of types of offices, either mechanically or by key sets at call distributing tandem positions. An installation of call announcer apparatus, described in last year's report, has been made in New York. The mechanical tandem also includes a trouble recorder which provides a continuous count of calls affected by various classes of irregularities and prints, by means of a teletypewriter, a complete record of the channels and equipment used by such calls.

The panel system has been provided with a new type of equipment known as the decoder for translating the digits dialed by the subscriber into the electrical information required for routing the call to various types of offices. Panel equipment in certain areas is also being arranged to permit subscribers to dial calls directly to distant zones which previously required the supervision of an operator because of the additional charges involved. The equipment is arranged to determine the number of message units corresponding to the charge to the zone in which the call terminates and to cause a corresponding number of operations of the message register.

Time announcement systems for use in the larger areas have been modified by the addition of facilities for the distribution of announcements over a trunk network, equipped with repeaters to insure adequate volume and quality, so that one operator may furnish time announcements for a network of offices.

An improved low-speed interrupter, utilizing mercury make and break contacts, has been developed for use in giving flashing signals to operators and in timing sequence operations. For producing tones used as signals to operators and subscribers, there has been developed an alternator which enables close control of the frequency, magnitude, and harmonic content of the tones. The field windings and the tone output windings of this alternator are formed on the stator, and the tone is produced by an unwound, toothed rotor which varies the magnetic flux in the tone windings.

Privacy apparatus was put into service during the year on nearly all of the intercontinental radio telephone circuits operated out of this country. By means of this apparatus the radio waves transmitting conversations are so modified in their characteristics that if listened to with an ordinary radio set, speech is not intelligible. At the receiving end this process is reversed and intelligible speech restored. While this does not guarantee complete secrecy, it does furnish a considerable degree of privacy and represents an important step in advance.

Another important toll equipment development was a new type of toll switchboard in which the use of smaller jacks makes possible a substantial increase in the number of trunks and toll lines appearing at each toll operator's position. Tandem positions are also provided through which an operator may secure access to any circuit not appearing in the toll line multiple at her position.

Outside Plant Construction and Methods

To facilitate the placing of tape armored toll telephone cables, a method has been developed whereby the trenching, laying of the cable, and the filling of the trench are simultaneously accomplished in one operation. This method utilizes a tractor behind which are pulled the trailer supporting the cable reel, the plow, and the drag which fills in the trench. From the reel, the cable is threaded through a pipe which leads it to the trench at a point directly in back of the plow. Under ordinary conditions it has been practicable, on the average, to lay more than one mile of cable per day with one outfit, using this method.

A new method which utilizes a single tube sleeve has been developed for making joints in aerial line wire. A hand operated rolling tool compresses the sleeve onto the wire in such a way as to provide a joint with no greater electrical resistance than a corresponding length of line wire and with a tensile strength at least equal to that of the wire. This new joint is expected to avert the electrical troubles now experienced with open-wire joints of the twisted sleeve type.

An important step has been taken by the communication interests cooperating with other pole using utilities, and others connected with the pole industry, in arriving at uniform classification dimensions for wood poles of southern yellow pine, western red cedar, northern white cedar, and chestnut. This work was carried on by the American Standards Association. Standard fiber strengths lb. per sq. in. have been established as follows: 7,400 for southern yellow pine, 5,600 for western red cedar, 3,600 for northern white cedar, and 6,000 for chestnut. These values have been accepted and made American Standards.

Under the new classification, a pole of a given class designation will have approximately the same breaking load regardless of pole length and species of timber. The adoption of the new grouping by all users of wood poles is expected to result in economies in the production and stocking of poles. The problems introduced by joint use will also be simplified as both parties to the joint use agreement will be using the same classification, whereas in the past this was seldom the case. Cost comparisons between the various species can be more easily made under the new classifications as prices may be directly compared class for class, whereas under the old tables calculations had to be made to determine the class of equivalent poles of other species of timber.

Long Distance Toll Cables

About 5,000 miles of cable for toll use were added to the telephone system of this country in 1930, bringing the total toll cable mileage to approximately 24,000 miles. Including the toll cable network on the Pacific Coast, which is connected with the toll cable network of the rest of the country by several individual and widely separated open-wire toll routes, there are now 129 out of 176 cities of the country having populations

of 50,000 or more connected directly into the toll cable network. The fourth telephone cable between Key West and Havana was completed in January 1931. The new cable is non-loaded and employs the recently developed paragutta insulation. It is equipped with carrier telephone apparatus which now provides three telephone message circuits, as well as one d-c. telegraph circuit. Provision has been made for the addition of other telephone circuits when needed. The telephone facilities now afforded by the single new cable are equal to those furnished by the three older cables in total. This gain in efficiency is brought about by improvements in the art of cable construction, including employment of paragutta, as well as advances in the application of carrier methods using high frequencies for multiplexing.

About 35,000 miles of telephone circuit are now being regularly utilized for radio program transmission service and almost 200 radio broadcasting stations receive programs from these chains of wire circuits. Heretofore practically all of this service has been furnished by means of open wires using voice-frequency channels. However, a new type of circuit for toll cables has recently been developed which permits of transmission over long distances without material distortion of a frequency range from 50 to 8,000 cycles, at the same time transmitting a volume range of about 40 db. (energy ratio 10,000 to 1). These characteristics are desirable for the satisfactory transmission of music where the frequency and volume range requirements are much greater than in the case of speech. This new type of cable circuit is loaded at 3,000-ft. intervals and special repeaters are placed at approximately 50-mile intervals. Associated with each repeater is an attenuation equalizer and a delay equalizer, which correct for the attenuation and delay differences at different frequencies. A paper on this subject, by Messrs. A. B. Clark and C. W. Green, was presented at the 1930 Summer Convention (A. I. E. E. TRANS., October 1930, p. 1514.)

CARRIER TELEPHONE AND TELEGRAPH

During 1930 about 160,000 channel miles of carrier telephone facilities and 400,000 channel miles of carrier telegraph facilities were installed in the United States. Recent improvements of carrier circuits involve improved transposition arrangements and the introduction of 8-in. spacing of wires in place of the 12-in. spacing. This latter development permits an increase in the number of facilities obtainable from a given number of wires on a pole line.

The operation of voice-frequency carrier telegraph over the channels of high-frequency carrier telephone systems has been successfully applied. For example, each of the three two-way channels of a carrier telephone system has been filled with 12 carrier telegraph channels. Such a pair of wires accommodates a duplex d-c. telegraph circuit, an ordinary two-way message telephone circuit and 36 duplex carrier telegraph channels which if multiplexed would afford means for the transmission of about 7,500 words per minute for the telegraph facilities alone.

A paper by Mr. E. I. Green, discussing the transmission characteristics of open-wire telephone lines, and a paper by Mr. L. T. Wilson, discussing telephone line insulators, were presented at the 1930 Summer Convention. (A. I. E. E. TRANS., October 1930.)

INTERCONTINENTAL TELEPHONY

Most notable of the advances made during 1930 in the intercontinental telephone field was the opening on April 3 of service to South America. This service is provided by a short-wave radio circuit operating between the transmitting and receiving stations at Lawrenceville and Netcong, New Jersey, and corresponding stations near Buenos Aires, Argentina. The ratio portion of this circuit is 5,300 miles in length and it is therefore, the longest circuit now operating from the North American continent. The transmission characteristics of this circuit are, however, somewhat better than those of the short-wave circuits between the United States and England, due principally to the fact that the transmission path of the South American circuit is further removed than is that of the North Atlantic circuit from the polar regions and the adverse influences of magnetic storms. Furthermore, the South American circuit, running nearly along the meridian, experiences a more uniform condition as to daylight or darkness. As a result of these factors, extreme variations in transmission, which form an important problem on the east- and west-bound radio circuits, are materially reduced on this circuit.

At Buenos Aires the radio circuit connects with wire and cable circuits to more than 325,000 telephones in the Argentine Republic, Chile, and Uruguay, including the cities of Santiago and Montevideo.

Another feature of interest during the year was the establishment of radio communication between the United States and Australia by way of London. At London the transatlantic circuits are connected to a London-Sydney short-wave radio circuit, which at Sydney connects in turn with the wire network of the Australian Telephone Administration. This combined circuit is approximately 14,000 miles in length.

Four papers, discussing transoceanic telephone service in its various aspects, were presented at the 1930 Winter Convention by Messrs. T. G. Miller, Ralph Bown, A. A. Oswald, and F. A. Cowan.

By the end of 1930, many parts of the world had been linked together by radio-telephone circuits in addition to those mentioned above. Most of these circuits have one end in Europe, far ends in such distant places as Brazil, Argentina, Australia, New Zealand, Siam, Indo-China, Java, and Algiers. Not all of these circuits are yet connected with the telephone systems at their terminals, and they do not all, therefore, possess to the same degree the universal accessibility and utility of those radiating from North America.

Ship-to-Shore Radio-Telephone Systems

A novel type of ship-to-shore service was inaugurated in the middle of the year through the equipment with radio-telephone apparatus of a New York City fire-boat. This equipment is arranged to enable continuous two-way telephone service between the master of the fire-boat and his land headquarters when the boat is under way. By means of this close communication, it has been possible to coordinate the efforts of the land and marine fire forces more effectively. As a result of the demand for telephone service of this kind in important harbors, both for harbor craft and ocean-going vessels, plans have been made for opening to such service in 1931, radio-telephone stations at Los Angeles, San Francisco, Puget Sound, and New York.

Commercial telephone service between ships at sea and the telephone system of the United States was extended during 1930 so that this service is now available to five ships: the Leviathan, Majestic, Homeric, Olympic, and Belgenland. Several organizations are involved in the provision of this service: the International Marine Radio Company, a subsidiary of the International Telephone and Telegraph Company, the Marconi Company, and the American Telephone and Telegraph Company. The shore stations are operated by the American Telephone and Telegraph Company on this side and by the British Post Office on the European side. During 1930, construction of a new land station at Ocean Gate, New Jersey, to care for transmission from shore to ship was completed. As in all radio-telephone transmitting stations, the antennas at this new station have a marked directional characteristic, the transmitted waves in this case being directed so as to traverse the North Atlantic shipping lanes. Four different wavelengths are used for transmission, ranging between 17.5 and 63 meters. Generally speaking, reliable transmission has been obtainable at distances from New York up to about 1,000 miles, corresponding with two days' sail. While satisfactory talks have been made at distances of 2,500 miles or greater, transmission at such distances has not been uniformly good.

A paper by Messrs. William Wilson and Lloyd Espenschied, discussing radio-telephone service to ships at sea was presented at the Northeastern District Meeting in May 1930.

Telegraphy

During 1930 all Western Union tickers handling New York Stock Exchange service in the United States were converted to the high-speed type. This permitted increasing the output of stock quotations from 300 to 500 characters per minute. In the field of telegraphic distribution of quotations and other market information, many improvements in apparatus and methods of operation were developed and applied during the year which resulted in a reduction of manual handling, greater output and extended operation into territory not heretofore reached, including quotation service to Cuba.

There has been a considerable expansion during the past year in the use of automatic quotation boards for electrically indicating market prices and this service has been extended to a number of other cities in addition to New York, where the first boards were installed.

Numerous additional installations have been made of concentration equipment for printing telegraph circuits. A description of the apparatus used for this purpose is contained in the paper entitled *A Printing Telegraph Concentrator* presented by Mr. W. B. Blanton at the Winter Convention in January 1931.

The Western Union Telegraph Company has developed a method whereby channels of a multiplex system circuit may be automatically repeated and extended individually over single wires by means of simplex printers to offices. Circuits from several offices using simplex printers may be grouped at a central point and combined into a multiplex circuit to a distant central office. This system will give many small offices direct outlets to the large centers which could not have been economically provided with previous methods.

During the year there was a marked increase in the tendency to employ, in place of direct current telegraph to outlying points superposed on telephone circuits, a method of operation which is called "two-path polar operation." This involves the use of independent one-way polar circuits for the two directions and affords improved service with a lower maintenance cost as compared to the usual polar duplex method.

Several methods of measuring the quality of telegraph transmission have been developed. One form of apparatus which has been found very effective both in the laboratory and the field was described by Mr. F. B. Bramhall in a paper entitled *Telegraph Transmission Testing Machine*, presented at the 1931 Winter Convention.

A paper describing various technical features in connection with the submarine high-speed duplex telegraph cable between Bay Roberts, Newfoundland and Horta, Azores was presented at the Winter Convention in 1931 by Messrs. J. W. Milnor and G. A. Randall. At the same convention, Mr. Milnor presented a paper on the influence of interference in submarine cables.

In addition to the statewide police teletypewriter systems in Connecticut and Pennsylvania, an extensive system of about 30 stations was installed last year in New Jersey for the New Jersey State Police. There is an increasing number of large city police networks, such as those of New York City, Boston, Buffalo, and St. Louis. The United States Coast Guard also has such a system in use along the New England Coast.

Progress has been made in the development of switchboards for teletypewriter service to permit the interconnection of these machines in a manner similar to that by which telephone instruments are interconnected.

A new type of belt conveyer has been developed by

the Western Union Telegraph Company for carrying telegrams between the various parts of the central office. In this conveyer messages are carried along between a steel channel and a moving flat belt about 1¾ in. wide, the motion of the messages being due to their sliding along the steel channel with practically no friction while adhering quite firmly to the belt. The messages can be taken around vertical or horizontal turns as well as through vertical and horizontal twists.

Municipal and Protective Signaling

There has been a steady increase in the use of electrical traffic signals. In the larger cities there have been several installations of flexible progressive systems, while in smaller places and in outlying sections of the larger cities, the detached intersection type of signal is still largely used. For important intersections and through traffic highways, vehicle controlled signals have been fairly successful but are expensive to install and maintain, as compared with the predetermined period signals. Vehicle control of signals obtained otherwise than by switches imbedded in the street surface, such as light beam control, has been tried out.

There has been a considerable use of electrical caution flashers in place of earlier types employing compressed gas, and practically all new installations are electrical. More illuminated caution signs are being installed and cheaper methods of illumination than by the neon tube method are being investigated

An important development of the past year concerning municipal fire alarms, has been the production of signal boxes and central office control apparatus, making effective use of ground return to send in alarms at such times as the circuit is in abnormal condition. Previous attempts to accomplish this introduced some abnormal condition on an otherwise normal circuit. This defect has now been practically overcome, and signal boxes have been developed that will operate in the usual manner on a normal circuit while at the same time they will transmit signals over a grounded, short-circuited or broken circuit without the necessity of making any temporary alterations at the signal box. While this development is too recent to be able to judge of its effects, it may permit of more leeway in circuit construction than is now considered safe, such as the installation of both sides of a circuit in the same aerial cable. The importance of this improvement may be estimated when it is considered that fires often occur at times when circuit conditions are apt to be disturbed by storm, explosion, or accident.

The use of single battery with trickle charger in place of duplicate batteries charged alternately by motor-generators is increasing with consequent increase in battery life.

The use of rectifiers and floating batteries or of transformers and a-c. circuits in connection with institutional fire alarms has progressed to such an extent that practically all new installations make use of public electric supply for the operating current in preference to primary batteries or to storage batteries charged from motor-generators. The practise of connecting automatic sprinkler alarm valves to municipal fire alarm boxes so that an alarm will be sounded automatically for any appreciable flow of water, has spread.

Experiments have been made on improved flash-light mechanisms for calling patrolmen to signal boxes. One such system has been installed lately in Boston. This permits any citizen desiring to call a policeman to operate an exposed lever which starts the flash-lights blinking the number of the signal box from which the call is made.

Television

Further advance was made in television as an accessory of telephone conversations by the development of means whereby two people at a distance are enabled both to converse and to see one another as if seated face to face in the same room. One of the interesting problems encountered in this development was that of sufficiently illuminating the faces of the parties engaged so that their images could be transmitted without, at the same time, dazzling their eyes to such an extent that they would be unable to see before them the image of the other party. This difficulty is met by employing blue light for scanning the faces of the parties. While the eyes are relatively insensitive to this color, the photoelectric cells used to pick up the light reflected from the face and generate the television signals are highly sensitive to it. Concealed microphones and loud speakers connected by four-wire telephone circuits are used in place of conventional telephone instruments to provide the talking portion of the system. The problem of operating a loud speaker and a sensitive microphone in the same small booth in such a manner that a self-sustaining singing circuit would not be created has been solved by specially treating the walls of the booth to prevent the reflection of sounds into the transmitter and by so locating both transmitter and loud speaker that the transfer of sound between them is minimized. While the experimental system is only two miles long, the television apparatus will function satisfactorily over distances of hundreds of miles when connected by suitable circuits as was shown by the one-way demonstration between New York and Washington.

Three papers dealing with television, by Messrs. H. E. Ives, F. Gray, M. W. Baldwin, H. M. Stoller, D. G. Blattner, and L. G. Bostwick, were presented at the 1930 Summer Convention. (A. I. E. E. Trans., Oct. 1930.)

Airplane Radio-Telephony

Development of telephone communication with airplanes continues to progress, and it has been found to be of very great importance for communication between transport planes and ground stations. Two-way radio-telephone apparatus for communication between planes

and ground has been developed and supplied for equipping a comparatively large number of planes. The value of such equipment may be indicated by the fact that legislation provides for increased revenue to air mail contractors flying planes equipped for two-way radio communication

Two papers on this subject were presented during the year, one by Mr. R. H. Freeman at the Pacific Coast Convention, the other by Mr. Eugene Sibley at the Middle Eastern District Meeting in October.

Synchronizing Radio Broadcasting Stations

There has been considerable experimental work carried on during the past year by the prominent radio organizations along the line of synchronizing broadcasting stations so that the same radio program may be broadcast from different stations operating at the same frequency. Best results are obtained only with a high degree of synchronism between the carrier frequencies of the different radio stations. In certain of the more successful experiments the control of the radio station frequencies has been carried out by sending over wire circuits standard frequencies of 4,000 or 5,000 cycles which, at the radio stations, are stepped up and used either directly to provide the radio carrier or indirectly to control the frequency of a local oscillator. While it is evident from the tests which were made that line circuits can be used very satisfactorily for transmitting control frequencies, certain requirements are imposed on the radio station frequency step-up equipment to iron out minor line fluctuations, which are, of course, greatly exaggerated when the frequency is raised from the relatively low frequency transmitted over the lines to the radio frequency of from 500 to 1,000 kilocycles.

Standardization of Radio Terms

During the past two years the Standardization Committee of the Institute of Radio Engineers has had under way a complete revision of definitions of terms, abbreviations, symbols, and methods of measurements and tests. A preliminary report of this work was issued in December, 1930.

Foreign Communication Matters of Interest

During the year international service was extended in Central America by the interconnection of Guatemala and El Salvador. In Mexico the subscribers of a second large network were given access to the United States and all points reached therefrom.

Conference toll service or multiple telephone service was established in the Netherlands. By means of this system from three to six subscribers in the same or different cities may be interconnected at the same time so that any one of the subscribers may be heard by all of the others.

Picture transmission service was extended in a number of countries, particularly in Japan.

In Europe the toll cable network was increased during the year by 6,000 to 8,000 kilometers. Two additional submarine cables were placed across the English Channel and one was placed between Sweden and Germany.

A complete rotary automatic exchange system was installed in Vatican City and connections were established with the international network.

Direct dialing over long distance telephone lines was successfully demonstrated in Europe and installations were made in several countries. Toll dialing has been employed in the United States to a limited extent for a number of years.

Transatlantic radio-telephone service was extended to include a number of new countries in Europe and to reach additional points in countries to which service had previously been given. Connections to points within the Antarctic Circle became possible for the first time when the service was extended in South America to include a number of additional cities in Argentina and Chile.

During the year the International Telephone and Telegraph Corporation, in cooperation with the government administrations concerned, opened direct radio-telephone links connecting Buenos Aires with Paris, Berlin, and London. These additional links between South America and Europe not only decrease the use of long land lines formerly required to serve points distant from the radio terminal, but greatly increase the reliability of the international connections as a whole. When, because of atmospheric disturbances or for other reasons, one link is unable to give commercial service, the traffic may be routed over one of the other links. The question of allotting the traffic over the different circuits and adjusting rates so that the rate between two points will not depend upon the routing of the call has been by no means a simple one, but with the cooperation of the various government administrations much progress has been made.

Commercial service was made available between telephone subscribers in Chile, Uruguay, and Argentina, and subscribers in Belgium, Denmark, Switzerland, Austria, Lithuania, Poland, Esthonia, Norway, Sweden, Czechoslovakia, and Jugoslavia through one or another of the four direct links from Buenos Aires which, of course, also serve Spain, France, Germany, and Great Britain.

Commercial telephone service was opened to some of the Canadian National Railway express trains and equipment for the reception of broadcast programs on moving trains was provided in a number of countries, including Jugoslavia, Italy, and Austria.

During the year technical development work continued to prepare for improvements in existing apparatus and methods as well as to explore new fields, such as signaling and dialing over radio-telephone circuits, and the use of the so-called ultra short waves, those of under five meters.

Cooperation Between Wire Using Companies

The many problems arising in coordinating the wire plants of the power and telephone companies led to the formation of the Joint General Committee of the National Electric Light Association and Bell Telephone System in 1921. Since that time an extensive program of investigation has been in progress and many important results of this work were published in 1930 as Volume 1 of Engineering Reports of the Joint Subcommittee on Development and Research. A review of the work of this subcommittee was given in a group of four papers presented at the 1931 Winter Convention as a symposium on the coordination of power and telephone plants.

During the last two or three years three other Joint General Committees have been organized with the general objective of working out methods of procedure for the coordination of wire plants. These are the Joint General Committee of the Western Union Telegraph Company and the National Electrical Light Association, the Joint General Committee of the American Railway Association and National Electric Light Association and the Joint General Committee of the American Railway Association and the Bell Telephone System. These committees are proceeding with the formation of the fundamental bases of procedure for the cooperative handling of mutual problems between the utilities concerned and the carrying out of such development and research work as appears to be necessary in connection with the problems involved.

Applications of Probability Theory in Telephone Practise

The importance of the probability theory and the related theory of statistics in telephone practise are, in a general way, well known by the engineering profession. However, a short résumé of the matter together with a brief statement of additional applications made during the last year may be welcome.

The oldest and best known application of the theory in the art of communication is its use in the determination of the loads which can be placed on various manual and dial trunking arrangements in order that efficient service be rendered. Unbalance effects on loaded circuits and other transmission lines of periodic structure also give rise to linear and other types of error function problems for the solution of which recourse to probability theory must be had.

The scheduling of adequate sampling plans for determining the quality of telephone equipment at various stages of its manufacture, after delivery to the operating companies and after installation, make heavy demands on probability and statistical theory. Within the last year extensive sampling schedules have been made for determining the extent to which the human factor in the telephone business is performing its assigned functions. For example, sampling theory is now being applied with reference to the performance of the repair clerk and test desk man, the quality of work done by installers and repairmen, the quality of subscribers' contacts in commercial offices and the quality of directory printing and delivery service.

Electric Welding

ANNUAL REPORT OF THE COMMITTEE ON ELECTRIC WELDING*

THIS report consists of two sections; the first dealing with the Organization and Policies, and the second with the Progress of the Art.

I. Organization and Policies

During its first three years, this newly created committee has gradually extended its field of action until the field overlapped that of various technical committees of the American Welding Society. It was necessary, therefore, to establish a clear understanding with the A. W. S. in order to create an exchange of information and to avoid duplication of effort. It became apparent that it would be more profitable to leave such problems as the metallurgy of the welding processes, methods of testing the completed welds and organization of the procedure control, to the committees of the A. W. S.

Our efforts have been concentrated, therefore, on sponsoring the advancement of the theory of the electric arc, the design of the electric welding apparatus and the use of electric welding processes in the manufacture of electrical machinery.

The gathering of all available information on the progress of the art and the presentation of these facts through the medium of our annual report to the whole membership of the Institute is another important function of this committee.

As the activities of our committee have increased, it was felt at the beginning of the present fiscal year that the time had come to organize several subcommittees composed of physicists and engineers especially interested in one of the above specific problems. The committee as a whole has been concerned with the general survey of the advance in the progress of the art.

The present organization of subcommittees is as follows:

Research (Phenomenon of the Electric Arc) Dr. S. Dushman, Chairman, Dr. J. Slepian, Mr. H. M. Hobart, Mr. W. Spraragen, Mr. A. M. Candy.

Electric Welding Machinery (Designs of) Prof. F. Creedy, Chairman, Mr. J. C. Lincoln, Mr. A. M. Candy, Mr. A. Churchward, Mr. H. M. Hobart, Mr. K. L. Hansen.

Resistance Welding. The subcommittee on Resistance Welding has only been partly organized with Mr. E. Lunn and Mr. H. W. Tobey gathering preliminary information.

Papers

Through the efforts of the members of our committee, a symposium on welding was presented during the Winter Convention of the Institute. A paper by Dr. G. M. Shrum and Mr. H. G. Wiest, Jr. was presented by Dr. S. Dushman which related to the new experiments of the phenomenon of the electric arc.

Three papers were presented by Mr. J. H. Blankenbuehler, Mr. S. R. Bergman and Professor F. Creedy on the subject of the design of electric welding generators.

Two papers by Mr. M. Thomson and Mr. S. Martin, Jr. were on the subject of the resistance welding as applied in the manufacture of electrical apparatus.

Another paper on the design of the electric welding generator was published in the JOURNAL of the A. I. E. E. prior to the above Convention, by Mr. C. J. Holslag.

II. Progress of the Art

General

The past year was characterized, first, by an outstanding improvement in the quality of the welds produced by various methods, secondly, by the refinement in the design of electric welding equipment, and thirdly, by the unprecedented expansion in the use of the resistance welding process.

The methods of testing and the procedure control attained such refinements that the quality of the welds produced on pressure vessels can be checked with accuracy.

The most outstanding accomplishment in the field of application of the electric arc in the past year, is the fabrication of 24 all-welded steam boilers by the Babcock & Wilcox Company for the United States Navy for installation on the new scout cruisers.

In the past, the arc welded oil stills for high pressure were manufactured successfully for a number of years by the A. O. Smith Corp., yet it is the first time that high-pressure steam boilers were fabricated by the electric arc and installed on the fighting ships.

Improvement in the Quality of Arc Welds

Arc welding was introduced into general use in this country during the World war. The first attempts to adopt the European method of welding with heavily fluxed electrodes, did not meet with general approval. Instead, the technique of welding with bare wire electrodes was developed to such an extent that practically

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P. P. Alexander, Chairman.

C. A. Adams,	K. L. Hansen,	Ernest Lunn,
A. M. Candy,	H. M. Hobart,	B. T. Mottinger,
Alexander Churchward,	C. J. Holslag,	J. W. Owens,
F. Creedy,	J. E. Kearns,	J. Slepian,
S. Dushman,	J. C. Lincoln,	William Spraragen,
F. M. Farmer,		H. W. Tobey.

all the arc welding in this country was done, until recently, by that method.

Since the tensile strength of the welds produced with such electrodes is about the same as that made by the most expensive heavily fluxed electrodes of European make, for many applications the bare wire is entirely satisfactory. It should be noted, however, that both bare wire electrodes and heavily fluxed electrodes of European make produced welds lacking in ductility.

With the extension of the field of application of arc welding, it soon became apparent that for the use of arc welding on such structures as pressure vessels, electrodes of different types would be needed. Over ten years ago, work in this direction was started by the Electric Arc Cutting & Welding Co., Wilson Welder & Metals Co., and some other concerns and individual investigators, each of whom produced a new type of heavy or lightly covered electrode. These electrodes had certain advantages over the bare wire electrodes.

Decided advance in the improvement of the quality of the welds was made a few years ago by the General Electric Co. with the hydrogen gas shielding of the weld, by A. O. Smith Corp. with special wood pulp covered electrodes, and by several other individual investigators and concerns, each of whom developed in the last year or two, a very efficient type of fluxed electrode giving welds of high ductility, a quality which is absolutely essential for work on steam boilers and many other types of pressure vessels.

At the present time, several manufacturers of pressure vessels, in advertising their welds guarantee a ductility unheard of only a few years ago. The General Electric Co., A. O. Smith Corp., Blaw-Knox Co., Struthers-Wells Co., Kellog Company, Fusion Welding Corp., The Lincoln Electric Co., and Babcock & Wilcox Co. are probably only a part of the list of concerns now producing highly ductile welds. This advance in the quality of the produced welds opened new fields for arc welding, of which the steam boilers for the United States Navy is an outstanding example.

Resistance Welding

The welds produced by this process are of the highest quality with respect to strength, ductility and resistance to fatigue. The development, therefore, consisted mostly in the improvements in the design of the welding machines and application of such machines in new fields.

The most outstanding feature of the past year was the great development of welding pipes by the resistance process. Several machines up to 6,500 kva. each have been built for welding, by the flash welded process, longitudinal seams 40 ft. long. By the use of such machines, a weld 40 ft. long is produced simultaneously all along the seam and in less than one minute on pipe some 24 inches in diameter and of a plate up to ½ inch in thickness. Similar resistance welding machines of 1,200-kva. capacity weld circumferential seams of similar pipe. All the electrical parts for the above machines have been built by the Swift Electric Welder Company. A spot welder of 800 kva. with electrodes of 3½ inches in diameter, which probably is the largest machine ever built in this country, has been successfully built by the same Company for special heavy welding work.

Other concerns (amongst which the Thomson-Gibb Electric Welding Co. is the pioneer), developed the continuous method of seam welding. This last method had previously been used on a large scale for welding thin walled tubing. Within the last year, this method has been applied to the continuous seam welding of pipe of considerable diameter and wall thickness. At the present time, several manufacturing concerns are producing welded pipe up to 40 ft. long and it is expected that by butt welding two of such lengths in the factory, a pipe of 80 ft. long will be available for construction work.

This great development in the welding of industrial pipe by the resistance process was due to the decision of several large concerns to extend the pipe lines for transportation of natural gas and gasoline from the producing areas to the consuming districts over 1,000 miles away.

This development should be of especial interest to engineers since it indicates the possibility of transmission of power over longer distances by gas than have been accomplished by the electric current.

As was remarked by a well-known consulting engineer, the electrical engineer should rise to the occasion and surpass gas with respect to distance and amount of power transmitted. He has plenty of as yet undeveloped alternatives to the 60-cycle synchronous system as at present employed.

The resistance welding process is being further developed in the application to the automobile industry where it greatly outdistances all the other welding processes. Another important field of application of resistance welding is the manufacture of wire goods which comprises even such fields as the welding of wire netting for reinforced concrete. Machines making up to 24 welds simultaneously have been built and are in successful use. In the fabrication of electrical machinery, the resistance process has already been applied on a large scale to the manufacture of small transformer tanks. The application of this process has also extended to the fabrication of motor magnet frames.

Structural Steel Welding

In the field of structural steel, arc welding has already proved to be entirely satisfactory, and therefore, received further important applications. All arc welding of this type of construction is done with entire satisfaction with the bare wire electrodes.

Amongst the high buildings erected during the past year, (partly by welding and partly by riveting) are the buildings of the Southern California Edison Co., the Edison Electric & Illuminating Co. of Boston, and

the DuPont Corporation at Wilmington, Delaware. The highest building entirely welded was erected by the Dallas Power & Light Co. This building has 19 stories and measures 246 feet above the foundations. The Westinghouse company erected several industrial and office buildings, all entirely welded. The highest of these buildings measures 190 feet above the foundations. It should be noted that in the erection of the buildings, only very few welding machines are necessary. In the erection of the 19 story building at Dallas, only four arc welding machines were used.

Shipbuilding

In the shipbuilding field, arc welding is being extended rapidly and all our shipbuilding companies such as the Newport News Shipbuilding & Drydock Co., The Bethlehem Shipbuilding Co., and many others as well as the U. S. Navy Yards, are using arc welding quite extensively for fabricating various internal structures on ships. On smaller ships, the electric arc has been used successfully even in welding the hulls.

The Electric Boat Company, at Croton, launched during the past year, an all welded barge, 118 ft. long, of Ewertz patented design. The Federal Shipbuilding & Drydock Co., at Curney, N. J., welded a number of barges, and the Standard Steel Shipbuilding Corp., of Los Angeles, completed an all-welded 65-ft. yacht.

The application of arc welding in shipbuilding requires a careful study of the design of the welds and the details of the technique of welding. The long welded seams characteristic in this type of construction may be subject to high internal stresses and therefore should be produced by the best known methods and electrodes. The amount of welding per ton of steel in shipbuilding is very much greater than in the erection of buildings where only the short welds are necessary. It may be expected that in the construction of barges and small vessels for internal navigation, arc welding will soon outdistance riveting.

Automatic Machines, Alloy Electrodes and Special Arc Torches

The design of automatic arc welding machines advanced still further and several concerns are now manufacturing either full automatic or semi-automatic machines of a very efficient design for use with metallic electrodes. The Lincoln Company made further improvements in automatic carbon arc welding machines which produce welds of high ductility, and the General Electric Company applied the atomic hydrogen process to automatic welding as well as for hand welding.

The development of special alloy electrodes for hand welding as illustrated by the Stoody process, made considerable progress. The surfacing of various parts of machines subject to wear and abrasion with hard surfaces in certain cases can be successfully accomplished.

The development of special torches for use of indirect arc (similar to the flaming arc) extended the field of arc welding to the low-melting-point alloys. A special torch developed by Hansen and utilizing the d-c. arc can now be used for brazing, soldering, and welding low-melting-point extruded alloys. Another torch utilizing the a-c. arc has also been put on the market by the Warner Co., of Los Angeles. It can be used successfully on light work of brazing, soldering, and welding steel sheets of light gage.

Design of Electric Arc Welding Generators

The advances and refinements in the design of the electric welding generators have been carefully followed by the subcommittee on Electric Welding Machinery, which reports as follows:

An outstanding feature of the year's work in the development of direct-current arc welding generators, is the attention which has been devoted to their transient characteristics. It has been realized that the momentary shortening of the arc produces a large momentary transient current, which tends to cause explosions or "sputterings" detrimental to welding. Means have, therefore, been sought by several workers by which these momentary transient currents may be eliminated and papers on the subject have been presented by Blankenbuehler, Bergman, Holslag and Creedy.

The direct-current welding generators contain a main exciting coil either shunt, separately excited, or a combination of the two, and a demagnetizing series circuit whose function is to reduce the voltage with increasing current. One important type of transient is caused by the voltage induced in the main exciting circuit by transformer action from the series demagnetizing circuit and this type of transient may be eliminated by reducing this voltage to a small value. There is no need to eliminate this voltage altogether because it is only necessary to reduce it to such a degree that the solutions of the differential equations which determine the current approximate to the logarithmic instead of the oscillatory type. Blankenbuehler discussed a machine with separately exciting coil and reverse series winding only, and injects into the separately excited circuit a voltage proportional to the current flowing through the reverse series winding (the welding current) by means of a series transformer. This voltage is opposite in direction to that induced in the same coil by the reverse series winding so that the two tend to cancel.

The machine treated by Bergman has two distinct poles whose flux cuts the conductors between positive and negative brushes. One has constant flux and the other is shunt excited from a third brush intermediate between the main brushes, armature reaction being relied upon to reduce its voltage with increasing current. In this case a series transformer is used to inject into this shunt circuit a voltage proportional to, but opposite in direction to that due to induction from the armature.

In Creedy's machine in which the effect of shunt and

separately excited windings is produced by a single coil, no transformer is employed but the same result is produced by reducing the reluctance of the main magnetic circuit so that the number of turns on the main exciting coil is very much reduced and consequently the e. m. f. induced in it by the series demagnetizing circuit becomes small. With this latter device a neutralizing winding becomes necessary to avoid sparking and excessive reactance of the armature winding.

Testing of Welds

Several non-destructive methods of testing of welds have been developed among which the X-ray method is already being applied as a regular procedure control on welds made on important structures. The magnetic and the stethoscope methods are also available. It should be noted also that a series of experiments has been conducted with the gamma rays produced by radium emanation for testing of welds on heavy plates and steel castings.

Further Research

Since the electric arc is the foundation on which the entire arc welding industry has been built, our subcommittee on Research recommends further study of this phenomenon. The outlined problems are as follows:

1. Probe measurements in arcs between iron electrodes, using a technique somewhat similar to that adopted by Nottingham in his investigations on the arc between copper electrodes in air.

2. Arc characteristics should be taken as a function of the pressure for different gases, such as carbon dioxide, air, and argon.

3. The question of the part played by fluxes, or additions of various "dopes" to the welding rod.

4. Determinations of the energy consumption at the electrodes, using a calorimetric method.

5. Accurate determination of cathode drop and its variations under varying conditions. This is an important factor in all theories of the electric arc and more accurate information on this point is certainly desirable.

6. Accurate determination of anode drop under varying conditions.

7. Study of small current arcs and particularly the glow to arc transition.

8. Mathematical study of some of the newer ideas on stability of discharges as developed by Barkhausen and others.

9. Cathode-ray study of stability of arcs such as used in electric welding. The spontaneous variations in current and voltage which are always taking place will probably be frequently beyond the capacity of the ordinary oscillograph. The influence of high frequency characteristics of the external circuit could be studied in this connection.

10. Stability of arc in magnetic field. Since arcs used in welding usually have quite strong magnetic fields, the influence of this factor in the stability of an arc is quite important.

11. Study of influence of nature of cathode surface on stability.

12. Study of influence of nature of anode surface on stability.

13. Study of passage of the deposited metal from the electrode to the work. Although a large part of the metal is deposited by liquid drops, it may be that a considerable portion passes in the form of vapor.

14. Study of the influence of superimposed alternating current of moderate and high frequency. The use of high frequency has been proposed for actual welding, but the influence upon the arc has not been studied in much detail.

It has also been suggested that the carbon welding arc be further studied, especially with respect to the blast of carbon vapor from the cathode spot.

University Activities

Through the initiative of the American Bureau of Welding, twelve engineering colleges and universities have become interested in various problems relating to welding. In addition to the research work conducted by professors, the students in several colleges write their theses on welding in preparation for the degree of B. S. or M. S.

It should be noted that welding, and especially electric welding, is receiving considerable attention in various universities abroad. Germany is probably leading in that respect because electric welding is considered to be of such importance that some colleges in that country confer the degree of Doctor of Engineering for any adequate research work on problems of welding.

In the Soviet Union, welding has received during the past year, an unprecedented expansion. To deal more adequately with the problem of a highly trained personnel, a special Welding Institute is being organized which will cost over $1,500,000, to train future welding engineers.

Electrical Machinery

ANNUAL REPORT OF COMMITTEE ON ELECTRICAL MACHINERY*

I. Organization and Activities

THE committee is organized with five permanent subcommittees, and its work has consisted of the review of papers, arrangement of programs for technical sessions, and the preparation of Standards and Test Codes.

Forty papers on electrical machinery were presented during the calendar year 1930. Others could have been made available if facilities for presentation and publication had permitted. The committee believes that the preparation of short and informal papers designed to bring out discussion at conventions should be encouraged, and that highly technical papers whose chief value is for reference should be presented before small groups in parallel sessions.

Standards

The Subcommittee on Transformers has been very active and during 1930 prepared "Recommendations for the Operation of Transformers" and brought to conclusion a revision of the A. I. E. E. Standards for Transformers.

The Subcommittee on Synchronous Machines, besides completing A. I. E. E. Standards for Capacitors, has initiated a number of revisions for the A. I. E. E. Standards for Synchronous Machines.

The Subcommittee on Mercury-Arc Rectifiers is working in close cooperation with the Sectional Committee on Rectifiers, which has under preparation Standards for Mercury-Arc Rectifiers.

Test Codes

Preliminary drafts of test codes for transformers, induction motors, direct-current machines and synchronous machines have been prepared. These codes are intended to provide definite instructions for the more generally applicable field and factory methods of conducting and reporting acceptance and other tests of general commercial value.

†Legend for Manufacturer Designation:

In order to conserve space and avoid numerous repetitions of the names of manufacturers, the following designation has been used throughout the report:

AC—Allis-Chalmers Manufacturing Co.
BB—American Brown Boveri Co.
CGE—Canadian General Electric Company
CW—Canadian Westinghouse Co., Ltd.
EM—Electric Machinery Mfg. Co.
GE—General Electric Co.
W—Westinghouse Electric & Mfg. Co.

*COMMITTEE ON ELECTRICAL MACHINERY:

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II. Resume of Progress of the Art

SYNCHRONOUS MACHINES

Steam-Turbine Driven Alternators

The size of the single-shaft units has again been increased, two 200,000-kva., 0.8 power-factor, 1,800-r. p. m., single-shaft, tandem-compound, turbine-generator units (GE)† now being built for the Hudson Avenue Station of the Brooklyn Edison Company. They have double windings rated at 16.5 kv., and double-winding auto-transformers will step up the voltage to 27.6 kv.

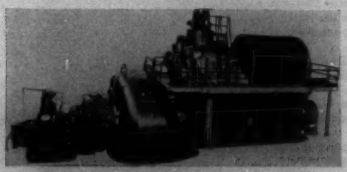

FIG. 1—50,000-KW., 3,600/1,800-REV. PER MIN., VERTICAL-COMPOUND, TURBINE-GENERATOR UNIT (GE)—PACIFIC GAS & ELECTRIC CO.

A 110,000-kw., 1,200-lb., vertical-compound, double-winding turbine-generator unit (GE), with duplicate generators on the high- and low-pressure turbines, has been constructed for the Ford Motor Company.

A 50,000-kw., 3,600/1,800-r. p. m., 1,200-lb. unit, in which the high- and low-pressure elements were combined to form a vertical-compound turbine-generator set (GE) was constructed for the Pacific Gas & Electric Company and a duplicate unit is nearing completion. (Fig. 1.)

Three 18,750 kva., 3,600-r. p. m., turbine-generator units (W), the largest machines of this speed yet manufactured in this country, were put in operation at Baton Rouge by the Louisiana Steam Products Company. An outstanding feature of these machines is the internal propeller fan used, the success of which has created a new interest in internal fans for large machines.

High-voltage turbine generators rated 121,000 kva., 18 kv.; 147,000 kva., 22 kv.; and 94,000 kva., 22 kv. are now in the first stages of construction (AC).

The satisfactory completion of tests on a 9,375 kva.

hydrogen cooled, turbine generator (W) (Fig. 2) have encouraged the serious consideration of hydrogen cooled turbine generators for ratings above 30,000 kva.

Waterwheel-Driven Alternators

The year 1930 has been notable for the number of large hydro-electric developments which have either been contemplated or put into operation. Table I is a list of some of the more interesting hydraulic-driven generators installed or under construction during the past year.

The 77,500-kva. generators (GE) for the Dnieper River Development in Russia, operating under a hydraulic head of 123 feet are the largest waterwheel generators yet constructed. (Fig. 5.) The total weight of each generator will be approximately 880 tons, the weight of the rotor and shaft will approach 445 tons, and the shaft itself, which is 36 ft. long and 40 in. in diameter, with a 70-in. flange on each end, will weigh about 68 tons. The stator is fabricated in six sections with punchings and windings assembled in each section before shipment.

TABLE I—WATERWHEEL-DRIVEN ALTERNATORS

Purchaser—Location	No.	Kva.	R. p. m.	Type	Fig.	Mfr.
Amtorg Trading Co.	4*	77,500	88.25	Vert	4	GE
Dnieper River (Russia)	1	77,500	88.25	Vert		GE
City of Seattle						
Skagit River	2	66,700	171.5	Umbrella		W
Inland Power & Light Co.	1	56,250	120	Overhung		GE
Ariel Development						
Alcoa Power Co.	4	50,000	120	Vert		CW
Chute-à-Caron						
New York Power & Light Corp.	1*	47,000	81.8	Overhung		GE
Spier Falls						
Beauharnois Power & Light Co.						
St. Lawrence River	2	46,625	75	Umbrella		CGE
St. Lawrence River	2	43,883	75	Umbrella		CGE
Western Power Co. of Can. Ltd.	1	44,000	120	Umbrella		CW
Ruskin Generating Station B. C.						
Lexington Water Power Co.						
Saluda Development	4*	40,625	138.5	Umbrella	3	W
New England Power Construction Co.						
Fifteen Mile Falls	4*	39,000	138.5	Umbrella		W
Shawinigan Engineering Co.	4	36,000	109.1	Vert		CW
Rapid Blanc Development						
Pennsylvania Water & Power Co.						
Safe Harbor, Susquehanna River	4	31,111	109	Overhung		GE
	2	31,111	109	Umbrella		W
New Kanawha Power Co.						
New Kanawha River	4	30,000	150	Vert		W
Pacific Gas & Electric Co.						
Tiger Creek	2	30,000	225	Horiz.		W
Gatineau Power Co.	1	28,500	125	Vert		CW
Paugan Falls P. Q.						
James MacLaren Co.	4	28,000	166.7	Vert		CW
Masson Power Development						
Shawinigan Water & Power Co.	1	25,000	112.5	Vert		CW
Grand Mere, P. Q.						
Toccoa Electric Power Co.						
Blue Ridge	1	25,000	164	Umbrella		W
Montana Power Co.						
Morony	2*	25,000	81.8	Umbrella		W
Hydro Electrica Espanola	2	25,000	375	Vert		GE
Spain						
Union Electric Lt. & Pr. Co.	6	23,888	112.5	Umbrella		W
Osage River						
Chats Falls Executive Board	8	23,500	125	Vert		CW
San Joaquin Light & Power Co.						
Merced Falls	1	4,000	128	Vert	4	W

*Included in report of last year.

The 31,111-kva., 109-r. p. m., umbrella-type generators (GE and W) for the Safe Harbor Development of the Pennsylvania Water & Power Company are to be driven by Kaplan-type turbines, and will operate as motors in a reversed direction to pump water back into the fore-bay for use during the peak-load periods.

High Frequency Generator

A 500-kva., 960-cycle generator (W) built for the American Brass Company will supply power for an electric furnace. The rotor required special construction to retain the field coils in place at the high peripheral speed of 20,000 ft. per minute.

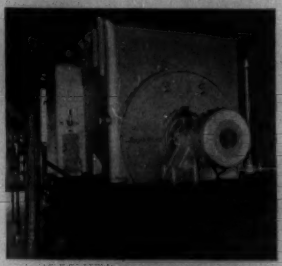

FIG. 2—9,375 KVA., HYDROGEN-COOLED, TURBINE-GENERATOR (W)

A 666-kva., 960-cycle single-phase generator (GE) was placed in operation at Watertown (Mass.) Arsenal in November, 1930, and a 750-kva., 960-cycle, three-phase generator (GE) is being built for the American Brass Company.

FIG. 3—FOUR 40,625-KVA., 138.5-REV. PER MIN., UMBRELLA-TYPE, WATERWHEEL-GENERATOR UNITS (W)—SALUDA DEVELOPMENT, LEXINGTON WATER POWER CO.

Synchronous Condensers

A 50,000-kva., 13.2-kv., 600-r. p. m., 50-cycle hydrogen-cooled condenser (GE), equal in capacity to the largest air-cooled machines, has been constructed for the Southern California Edison Company. (Fig. 6.) The total capacity of hydrogen-cooled condensers now in service is 137,500 kva. with 70,000 kva. additional on order.

Two 15,000-kva., outdoor hydrogen-cooled condensers (W) have been constructed; one rated at 50 cycles, 750 r. p. m. for the Southern California Edison Company, and the other rated at 60 cycles, 720 r. p. m. for the Indiana & Michigan Electric Company.

A 7,500-kva., 6.6-kv., 900-r. p. m., 60-cycle air-cooled, outdoor condenser (AC) has been constructed for the Central Illinois Public Service Company. (Fig. 7.)

Industrial Synchronous Motors

The application of synchronous motors to industrial purposes is being extended as the knowledge of the starting, acceleration, and pull-in requirements is increased and as the prediction of these characteristics becomes more exact. A number of unique designs has been developed during the year.

A 500-hp., 72-r. p. m., vertical-shaft motor (GE) has been applied to a Fuller Lehigh coal pulverizer, in which the motor frame forms the base on which the pulverizer is built. The motor develops considerably more than normal torque from start to pull-in in order to obtain successful starting with a choked mill. Overvoltage for starting is supplied by a step-up autotransformer.

FIG. 4—4,000-KVA., 128-REV. PER MIN., VERTICAL-TYPE, OUTDOOR, WATERWHEEL GENERATOR (W)—MERCED FALLS, SAN JOAQUIN LIGHT & POWER CO.

A 700/350-hp., 2.3-kv., 277/138-r. p. m., three-phase, 60-cycle, two-speed synchronous motor (W) has been applied to a vertical centrifugal pump for the Ford Motor Company.

A new method for securing reduced starting kva. has been introduced, which utilizes the inherent reactance of the motor itself, a 3,000-hp. (GE), five 3,500-hp. (EM) and several smaller motors having been built. The stator is wound with two or more parallel circuits so arranged within the core as to obtain increased reactance when only one of the circuits is energized. The starting characteristics obtained are somewhat similar to those secured by using external reactors in series with the lines.

A 600-hp., 440-volt, 300-r. p. m., three-phase, 60-cycle, synchronous motor (EM) was applied for the first time for continuous reversing duty on a copper

rolling mill, synchronous motors having been generally considered unsuitable for constant reversing duty on account of their inferior starting characteristics. The operating requirement that the mill be reversed from full speed forward to full speed reverse in five seconds necessitated special design of the stator and rotor to

FIG. 5—77,500-KVA., 88.25-REV. PER MIN., VERTICAL-TYPE, WATERWHEEL GENERATOR (GE)—DNIEPER RIVER DEVELOPMENT (RUSSIA) AMTORG TRADING COMPANY

dissipate heating, which was accomplished by the use of ventilating spacers in the armature core and field poles and by special cage end-ring construction. (Fig. 8.) Three parallel circuits were used in the stator, which were switched successively both for forward and reverse acceleration in order to reduce the increment starting kva. demand.

A slow-speed, vertical-shaft motor (EM) has been incorporated in a pulp hydrator base. The motor was

FIG. 6—50,000-KVA., 13.2-KV., 600-REV. PER MIN. 50-CYCLE, HYDROGEN-COOLED SYNCHRONOUS CONDENSER (GE)—SOUTHERN CALIFORNIA EDISON CO.

provided with a thrust bearing which carries the weight of the rotor and hydrator rotating member. To permit adjustment of the clearance between the rotating and stationary members of the hydrator, the motor was provided with a micrometer raising and lowering device, the field poles being slightly longer than normal to permit a moderate movement of the rotor axially with respect to the stator.

Marine Synchronous Motors

Several electric-propelled vessels of interesting design were placed in service or are under consideration.

TABLE II—MARINE SYNCHRONOUS MOTORS

Vessel (or purchaser)	No.	Hp.	R. p. m.	Mfr.
S. S. Santa Clara	†2	6,300	120	GE
S. S. Morro Castle	†2	8,000	143	GE
S. S. Oriente	†2	8,000	143	GE
S. S. President Hoover*	†2	13,250	133	GE
S. S. President Coolidge	†2	13,250	133	W
United Mail S. S. Company (6 vessels)‡	12	5,500	125	GE

*Launched December 1930, Transoceanic service 1931.
†Included in report of last year.
‡Under construction

The 13,250-hp., 133-r. p. m. ship-propulsion motors (GE, W) are the largest marine synchronous motors yet built. These motors are completely fabricated.

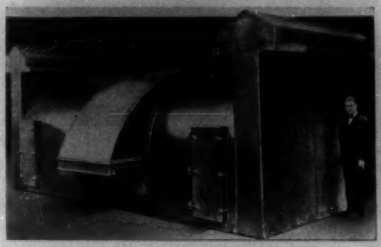

FIG. 7—7,500-KVA., 6.6-KV., 900-REV. PER MIN. 60-CYCLE, AIR-COOLED, OUTDOOR, SYNCHRONOUS CONDENSER (AC)—CENTRAL ILLINOIS LIGHT CO.

Frequency Converters

There is a growing tendency to install large machines outdoors in order to reduce building costs. The first frequency-converter units to be so installed have been built during 1930 and will be placed in operation during 1931.

Two such units, the generators being rated at 21,000 kva., 0.7 power factor, 300 r. p. m., 25 cycle, one-phase, and the motors at 18,000 kva., 0.9 power factor, 300 r. p. m., 60 cycle, three-phase (W) will be installed at the Wayne Junction Substation of the Philadelphia Electric Company to supply power for the new Reading Railroad Electrification (Fig. 9). Conventional indoor design was followed, with spring mountings to absorb the single-phase torque pulsations, the machine being adapted for outdoor service by enclosing in a sectionalized sheet steel housing approximately 64 ft. long by 25 ft. wide.

INDUCTION MACHINES

A major activity of the manufacturers during the year has been the development of new lines of induction

motors to conform with the frame sizes and mounting dimensions standardized by the National Electrical Manufacturers Association as announced in last year's report. In many cases this program has included a change in electrical design to improve the noise and torque characteristics. Much attention has also been given to the appearance in order to meet the ever more exacting aesthetic tastes of the public.

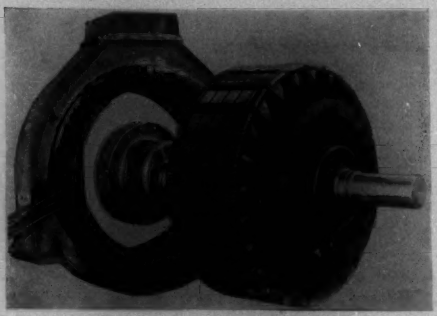

FIG. 8—600-HP., 440-VOLT, 300-REV. PER MIN. 60-CYCLE, CONTINUOUS-REVERSING-DUTY, SYNCHRONOUS MOTOR (EM)—COPPER ROLLING MILL

Several manufacturers now furnish lines of motors in integral up to 100 hp. as well as fractional horsepower sizes for class I and class II hazardous locations (inflammable gases and combustible dust) as defined in the National Electrical Code.

Complete lines of totally-enclosed, fan-cooled continuous duty 55-deg. cent. motors as large as 250 hp., particularly suited for use in harmful dust conditions, have now been developed by many manufacturers and the use of this type is steadily growing.

An extensive application of a novel induction motor (GE) has been made to conveyor tables in steel mills. (Fig. 10.) The conveyor roller is a hollow cylinder mounted on ball or roller bearings rotating around a stationary supporting shaft on which the stator is mounted. The cylindrical convey roll, which surrounds the stator, serves as a secondary, the induced currents flowing in the solid steel inner surface of the roll.

D-C. MACHINES

Motors and Generators

An 8,000-hp., 800-volt, 40- to 100-r. p. m., motor, having a peak capacity of 22,000-hp., 2,900,000-lb. ft. torque, has been built (GE) for a blooming mill of the Illinois Steel Company. This is the largest single-armature motor employing fabricated construction for the major parts.

Two 5,000-hp., 40-r. p. m., double-armature motors were built (W) for operating the main rolls of the new 10,000-hp. blooming mills at the South Chicago Plant of the U. S. Steel Corporation, which is the most powerful mill yet built. Each of the two main rolls is driven by one of the motors, the two being kept at the same speed by electrical control instead of being geared together as in former installations. Each double motor has a peak-torque capacity of two million lb. ft. Power is supplied from three 3,000-kw. induction motor-generator sets. The series fields of the three generators are interconnected in such a way that parallel operation is secured with satisfactory division of load.

Planer motors up to 75 hp. rating with speed ranges by field control of 6 to 1 have been developed (GE and W), and further increases in size of this class of motor are under consideration.

A 50-hp., 1,600-r. p. m., 75-deg. cent. one-hour motor has been developed (W) for application on a coal cutter to meet a limiting over-all height of 12 in.

Six 3,500-hp., 330-r. p. m,, motors have been constructed (AC) for a 96-in. plate mill of the Illinois Steel Company. Power is supplied by two 6,000-kw. synchronous motor-generator sets.

Two motor-generator sets, consisting of two 3,000-kw., 600-volt, compensated generators driven by one 6,500-kva. synchronous motor, have been constructed (GE). These sets will deliver 6,000 kw. continuously with 9,000 kw. for two hours or 7,500 kw. continuously without overload.

Exciters

Further developments in "rapid response" exciters have occurred during the year, with the objects of

FIG. 9—21,000/(18,000)-KVA., 300-REV. PER MIN.. 25-(60)-CYCLE, ONE (THREE) PHASE, FREQUENCY-CONVERTER OUTDOOR HOUSING (W)—WAYNE JUNCTION SUBSTATION, PHILADELPHIA ELECTRIC CO.

securing higher efficiency and improved control. The use of a special Wheatstone Bridge type of rheostat (GE) enables the exciter to operate down to zero or even reversed voltage.

A 90-kw., 3,600-r. p. m., direct-connected, turbine-generator exciter has been developed (W) which is one of the largest exciters ever built for this speed. (Fig. 11.)

Synchronous Converters

Four 5,440-kw., 167-r. p. m., 16,000-ampere, 25-cycle, synchronous converters were constructed (2 GE and 2 W) for a chemical plant in the Niagara Falls District. The converters are enclosed in volute housings, and the

outgoing air is discharged outside the building. Direct-current voltage adjustment is obtained by means of tap-changing equipment on the supply transformers. A novel feature of construction used on two of these machines (GE) is a "tandem" commutator, which consists of two sets of shorter copper segments, together with insulation and clamping rings, mounted on a common support so arranged that air can pass between the adjacent ends of the two commutators where their segments are connected together. This construction (Fig. 12) results in lower temperature rise and smaller expansion strains and, consequently, a smoother running surface than is usually obtained with an equivalent single-unit commutator.

Transformers

Power Transformers

Extensive theoretical and experimental study of transient voltage phenomena was continued during the year, and the development of means for protection against lightning surges advanced rapidly. One indication of the progress made during the year is given by the successful outcome of full voltage flashover tests on a large transformer.

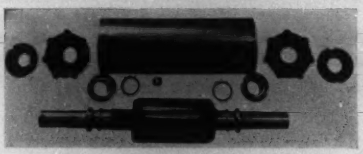

Fig. 10—40-Lb.-Ft., 250-Volt, 125-Rev. per Min., 25-Cycle, Conveyor-Roller Induction Motor (GE)

A 13,000-kva., 230-kv., wye-grounded, non-resonating transformer built for commercial use (GE) was subjected to a series of artificial lightning voltage tests. The transformer was connected to a lightning generator by a short transmission line insulated with fourteen 10-in. units, spaced 5¾ in. in suspension, which is used quite generally for 230-kv. service. The insulator strings were repeatedly flashed over without apparent damage to the transformer. The line insulation was then increased until the transformer bushings were flashed over. The transformer was subjected to repeated waves both above and below the bushing flash-over voltage, after which it withstood all A. I. E. E. standard tests.

A study of transient voltage phenomena within auto-transformer windings resulted in the development of the non-resonating auto-transformer (GE), of which several have now been built for 230-kv. service.

Through the development of the grounding neutral impedor (GE), the use of the non-resonating transformer was extended to include banks with neutrals isolated or grounded through resistance or reactance.

Investigation (W) has shown that a comparatively high resistance can be used in the neutral of a bank of power transformers and the bank will perform practically the same as though it were solidly grounded. The same result can be obtained with reactance in the neutral paralleled by a protective device, such as a lightning arrester. The internal voltages at points within the winding have been found to be practically identical for a bank with a solidly grounded neutral and for one with a reactance paralleled by a lightning arrester.

Fig. 11—90-Kw., 3,600 Rev. per Min., Direct-Connected, Turbine-Generator Exciter (W)

In order to extend the benefits of load-ratio control to small transformers, a lighter type of equipment has been developed for 15-kv. service (GE). This consists of a multi-point switch which permits the load current to leave each tap point over two paths; *i. e.*, over two switch arms which connect to the bridging reactor. A typical application of this equipment is represented by a 3,333-kva., 69.7/115 Y-13.8-kv., one-phase transformer, in which thirteen operating positions are provided by the installation of the control device in the low-voltage winding. In this type of construction all moving parts, that is, the ratio adjuster and two contactors, are mounted outside the main transformer tank.

Fig. 12—5,440-Kw., 340/270-Volt, 16,000-Ampere, 25-Cycle, Shunt-Wound, Synchronous Converter with Tandem Commutator and Brushes (GE)

Several 5,000-kva., 13.2-kv., three-phase, furnace transformers, with a new type of tap-changing equipment, have been built (W) for the Ford Motor Company. These transformers deliver a normal low-voltage current of 12,800 amperes at 225 volts, with a maximum current

of 19,200 amperes at 150 volts. A special motor-operated tap changer provides six different delta low voltages and a change from delta to star on the high-voltage winding gives six additional delta low voltages. Two individual tap changers are operated by one motor and all the voltages and connections are obtained by the operation of a single control switch at the switchboard.

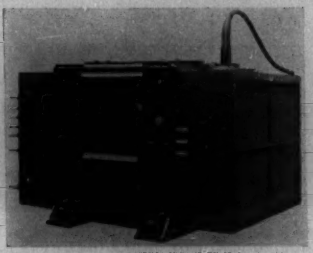

FIG. 13—4,200 KVA., 11,000,-915-46 VOLTS, 25-CYCLE, AIR-BLAST, LOCOMOTIVE TRANSFORMER (GE) (W)—PENNSYLVANIA R. R.

A 4,200-kva., 11,000-915-46-volt, air-blast transformer of special construction was built (coordinated design of GE and W) for installation in a locomotive where space is at a premium. (Fig. 13.) It was, accordingly, designed for minimum dimensions and weights, the floor space occupied being 6 ft. 8 in. by

FIG. 14—OUTSIDE-EDGE-WELDED TRANSFORMER RADIATOR (W)

7 ft. 3 in. and the total weight being approximately 26,000 lb. A 2,800-kva. transformer of the same type has also been developed. These transformers are suction air-cooled and of exceptional mechanical strength, being braced and insulated for the severe operating conditions incident to locomotive service.

Power-Transformer Auxiliaries

While the method of cooling transformers by means of "banked" radiators was not used to any great extent following its development several years ago, it was extensively applied during the past year. About 200,000 kva. in transformers of this construction are in service and more than 600,000 kva. are now under construction (GE).

A new type of transformer radiator has been developed to replace the tubular type on all Westinghouse large self-cooled power transformers. (Fig. 14.) All of its joints are formed with edge welds on the outside of the radiator, and there are no crevices or flat surfaces where water can accumulate. The open construction facilitates cleaning and painting.

A 20,000-kva., 66-22-kv., load-ratio-control transformer, equipped with unusual pothead disconnecting switches has been built (W) for the State Line Generat-

FIG. 15—100-KVA., 2,080-115/230-VOLT, 60-CYCLE, DISTRIBUTION TRANSFORMER EQUIPPED WITH DETACHABLE BUSHING (AC)—COMMONWEALTH EDISON CO.

ing Company. These high-voltage switches disconnect the transformer from the line and connect test bushings to the 66-kv. cable lines, which can then be tested with 330 kv., direct current. The pothead equipment also included oil reservoirs used to maintain pressure on the oil-filled cables to which the transformer is connected.

A new no-load ratio adjuster has been developed (BB) which is operated through the side of the tank wall instead of the cover, making it more convenient to operate and permitting the tap position to be safely checked without deenergizing the transformer. A novel form of connection is used between the internal and external parts which permits engagement or disconnection of the two parts, when the transformer core is tanked or untanked, without the necessity of crawling inside to remove pins, bolts, etc.

Distribution Transformers

A new single-bushing, single-phase transformer has been designed (GE) for 110-kv. rural service. It is arranged for connection from line to neutral on a 110-

kv. circuit, which is insulated for 132-kv. service. In order to secure a low over-all height, the interior was so constructed as to give the equivalent of an inverted winding. The bushing was then connected to the bottom of the coil stack, thereby effecting a low height in spite of the large size of the bushing and the amount of insulation required for operation on a 132-kv. insulated line.

A detachable bushing has been developed (AC) for distribution transformers, particularly for installation where lightning conditions are abnormally severe, which can be replaced without removing the case from the pole. (Fig. 15.)

Rectifiers

The installation of rectifiers has continued to increase at a rapid rate, particularly when measured in terms of the aggregate kw. capacity.

	No.	Kw.
Put into operation during 1930	33	75,225
Put into operation during 1929	30	48,125
Increase	10%	58%
Put into operation during 1930	33	75,225
Being erected during 1930	26*	71,400*
On order at end of 1930	29	79,275
Total for 1930	88*	225,900*
In service at end of 1929	90	102,309
Grand total	178*	328,209*

*In addition one spare 500-kw. rectifier tank (without transformer) was supplied.

The mercury-arc rectifiers put into operation and being erected during 1930 and on order at the end of the year are shown in Table III.

The placing in operation of fourteen units with an aggregate rating of 40,000 kw. of 3,000-volt rectifiers

TABLE III—MERCURY-ARC RECTIFIER UNITS PUT INTO OPERATION DURING 1930 OR ON ORDER DECEMBER 31, 1930

Purchaser	No. of sets	D-c. volts	Kw. per set	Total kw.	Control	Service	Put in service	Manufacturer
American Gas & Electric, New York	2	610	500	1,000	Automatic	Railway	On order	Brown-Boveri
Boston Elevated Railway	2	600	3,000	6,000	Automatic remote control	Railway	Being erected	General Electric
Chile Exploration Co.	1	650	1,000	1,000	Automatic	Heavy mine haulage	1930	General Electric
Clinton, Davenport & Muscatine Railway	1*	700	500	500*	Automatic	Railway	Being erected	Brown-Boveri
Commonwealth Edison Co.	2	1,500	1,500	3,000	Manual	Railway	1930	Brown-Boveri
Commonwealth Edison Co.	4	625	3,000	12,000	Manual	Railway	1930	Brown-Boveri
Commonwealth Edison Co.	3	625	3,000	9,000	Manual	Railway	Being erected	Brown-Boveri
Commonwealth Edison Co.	3	625	3,125	9,375	Manual	Railway	Being erected	General Electric
Consolidated Mining & Smelting Co. of Canada	2	650	6,500	13,000	Manual	Electrolytic	On order	Brown-Boveri
Consolidated Mining & Smelting Co. of Canada	1	650	6,500	6,500	Manual	Electrolytic	On order	General Electric
Delaware, Lackawanna & Western R. R. Co.	12	3,000	3,000	36,000	Manual	R. R. electrif'n	1930	General Electric
Delaware, Lackawanna & Western R. R. Co.	2	3,000	2,000	4,000	Automatic remote control	R. R. electrif'n	1930	General Electric
Detroit, City of	1	600	2,000	2,000	Automatic	Railway	On order	General Electric
Edmonton, City of	1	575	1,325	1,325	Manual	Railway	1930	Brown-Boveri
Hershey Chocolate Company	1	600	500	500	Manual	Interurban-railway	1930	General Electric
I. G. Farbenindustrie for Standard Oil Co. of Louisiana	1	3,500/9,600	2,200	2,200	Manual	Electro-chemical	Being erected	Brown-Boveri
Iowa Nebraska Light & Power Co.	1	600	1,000	1,000	Manual	Railway	1930	Brown-Boveri
Italian State Railways	2	2,900	2,000	4,000	Automatic	R. R. electrif'n	1930	General Electric
Long Island Railway Co.	5	650	3,000	15,000	Automatic	Railway	Being erected	Brown-Boveri
Los Angeles Railway Corp.	2	600	1,500	3,000	Automatic remote control	Railway	On order	General Electric
Montreal Tramways Co.	2	600	1,500	3,000	Automatic remote control	Railway	Being erected	General Electric
Montreal Tramways Co.	2	600	1,500	3,000	Automatic remote control	Railway	1930	General Electric
New York Board of Transportation	10	625	3,000	30,000	Automatic remote control	Subway	Being erected	General Electric
New York Board of Transportation	13	625	3,000	39,000	Automatic remote control	Subway	On order	General Electric
Northern Indiana Public Service Co.	1	1,500	3,000	3,000	Automatic	Railway	Being erected	Brown-Boveri
Paris Orleans Railway, France	1	1,500	1,500	1,500	Automatic	R. R. electrif'n	On order	General Electric
Philadelphia, City of	2	630	2,500	5,000	Manual	Subway	1930	Brown-Boveri
Public Service Co. of No. Ill., Chicago	1	600	1,900	1,900	Manual	Railway	1930	Brown-Boveri
Public Service Co. of No. Ill., Chicago	1	600	1,900	1,900	Automatic	Railway	1930	Brown-Boveri
Quebec Power Co.	1	550	1,200	1,200	Automatic	Railway	Being erected	Brown-Boveri
Regina, City of	1	575	1,200	1,200	Manual	Railway	On order	Brown-Boveri
Saskatoon, City of	1	575	600	600	Automatic	Railway	1930	Brown-Boveri
Trenton Transit Co.	3	600	1,400	4,200	Manual	Railway	On order	Brown-Boveri

Totals:		
Put in service	33	75,225
Being installed	26*	71,400*
On order	29	79,275
Grand total for year	88*	225,900*

*In addition one spare 500-kw. rectifier tank (without transformer) was supplied.

on the Delaware, Lackawanna & Western Railroad Electrification (Fig. 16) was the outstanding event of this year. This is the first installation of 3,000-volt rectifiers in the United States and the first use anywhere

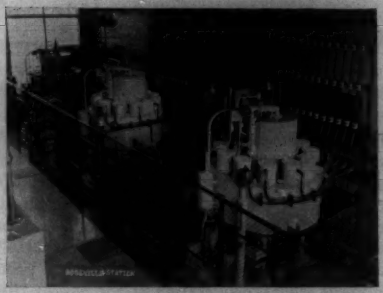

FIG. 16—3,000-KW., 3,000-VOLT, MERCURY-ARC RECTIFIERS (GE)—ROSEVILLE SUBSTATION, DELAWARE, LACKAWANNA & WESTERN R. R. ELECTRIFICATION

of so great a capacity of such units. It is also the first instance of a major railroad electrification relying entirely on rectifiers for the supply of power. These rectifiers are equipped with excited grids and with automatic compounding.

Another outstanding feature is the very large number of units ranging in voltage from 550 to 650 volts with a current rating in excess of 3,000 amperes, notable among which are 23 sets (GE) with an aggregate capacity of 69,000 kw. on order by the New York Board of Transportation. (The first seven units of this order were reported last year under the heading "City Subways of New York.")

Five units (BB), having a normal rating of 4,650 amperes at 650 volts, with overload ratings up to 15,000 amperes for twenty seconds, are being erected for the Long Island Railroad (Fig. 17). These rectifiers have eighteen anodes and normally operate from a 25-cycle source of supply but are arranged for immediate throw-over to a 60-cycle source of supply in the event of failure. The transformers are also suitable for operation at either 11 or 33 kv.

A 2,200-kw., high-voltage electric furnace set is also being erected (BB). The d-c. voltage may be varied from 3,500 to 9,600 volts by means of load-ratio control on the rectifier transformer. This is the highest voltage

FIG. 17—3,000-KW., 650-VOLTS, MERCURY-ARC RECTIFIER (BB)—LONG ISLAND R. R.

for commercial rectifiers which has been reported in this country. Smaller units of higher voltage have, however, been used for large radio broadcasting stations in Europe.

Electrochemistry and Electrometallurgy

ANNUAL REPORT OF COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY*

THIS report covers the period 1929 and 1930, inasmuch as no report was made in 1929.

It is believed worthwhile to indicate the magnitude of the electrochemical and electrometallurgical industries in terms of installed capacity and yearly power consumption. The figures for the United States are as follows:

Approximate installed operating capacity, kw	7,000,000
Approximate percentage of National total generating capacity	18
Approximate annual power consumption, kw-years	4,900,000
Approximate percentage of total	36
Number of workers	1,000,000
Value of product	$12,000,000,000

Quantities and percentages such as these would seem to warrant the liveliest interest on the part of men having electrical engineering training, particularly the younger men who find themselves faced with limited opportunities for advancement in those more standardized fields of the electrical art involving the design and manufacture of apparatus for the production and distribution of electrical energy. The development of new materials or processes based upon the utilization of this power is a field requiring talent of high order and one which it seems should be very attractive to men of electrical training who can and will superpose on an electrical background a knowledge of the fundamentals of physical chemistry.

Below is given a list of the more important industries whose basic processes are dependent upon the utilization of electricity for other than mechanical purposes:

Production of Metals by Wet Electrolysis. Copper, Nickel, Sodium, Zinc.

Production of Metals from Fused Electrolytes. Aluminum, Barium, Beryllium, Calcium, Magnesium.

Non-Metallic Electrolytic Products. Caustic, Chlorine, Hydrogen, Oxygen.

Electrothermic Products. Abrasives, Carbides, Carbon, Ferro-Alloys, Graphite, Refractories.

Miscellaneous. Cleaning and Surface Treatment of Metals, Dry Cells, Electric Steel Melting, Electrolytic Synthesis Organic Compounds, Electroplating, Electrostatic Precipitation, Inductive Melting and Heating, Nitrogen Fixation, Pasteurization and Sterilization, Secondary Batteries, Water Purification, Welding.

When the process problems of these industries are analyzed it will be found that they should be attacked by men who have been trained to deal with intangibles, and that most of the phenomena may be resolved into elements among which an electrical engineer who has been soundly trained in the basic science of his art should feel at home. Pursuit of these problems will probably lead him far from consideration of the newest thing in circle diagrams or the latest refinement in slot design but he will have broader scope for his imagination and the mental technique bred by electrical training.

The foregoing comments have been made because there are many who feel that the electrical industry is more in need of increased outlet for power than of further small gains in the efficiency of electrical apparatus *per se*, and that the great body of expectant young electrical engineers must look for adequate opportunities for advancement more to the fields of utilization and electrical processes than to the conventional ones of apparatus and generation.

Below is given an outline of the more important developments in electrochemical and electrometallurgical art that have become known during the past two years.

Copper

Although copper refining is probably the largest of the electrochemical industries in point of tonnage, no important modifications of electrochemical process have been reported although operating economies have been improved by advances in mechanical equipment and materials handling facilities.

Sodium

Metallic sodium is now being produced on such a large scale and so cheaply by electrolytic methods that it is the cheapest pure metal in terms of cost per unit volume. Its electrical conductivity is high enough so that its cost on a conductivity basis is lower than that of any other metal. These facts have led to a proposal that electrical conductors be formed of metallic sodium enclosed in a thin-walled tube of some non-magnetic alloy steel.

Metallic sodium is finding increasing application in connection with certain synthetic organic reactions

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whose nature is not disclosed and certain electrochemical interests are said to be preparing to manufacture sodium on an unprecedented scale.

Zinc

The success of electrolytic zinc refining plants was noted in the 1928 report of this committee. This development has since been subject to severe competition because of improvements in thermochemical methods. Electrothermal methods have also received the attention of investigators and it is probable that another year will see marked changes in zinc technology due directly to the application of electricity in one way or another.

Aluminum

The Hoopes process of producing very pure aluminum has become of increasing commercial importance, particularly for containers for various articles in the drug and pharmaceutical field. Although the electrical conductivity is appreciably higher than that of ordinary commercial aluminum it has not been commercially applied as electrical conductor material. Accurate alloy investigations have been made possible by this very pure material and the knowledge thus gained has assisted materially in the development of the strong aluminum alloys.

The usual Hall process rarely produces aluminum purer than 99.7 per cent, while the Hoopes process is regularly producing metal better than 99.98 per cent pure and some metal has been produced by this process having a purity of 99.99 per cent. The process is carried out in a three-layer cell, wherein the metal to be purified exists as a molten anode alloy and rests on the bottom of the cell. The electrolyte consists of a mixture of cryolite, aluminum fluoride and barium fluoride. The purified aluminum is electrolytically deposited in a layer of pure molten aluminum floating on top of the electrolyte. Graphite electrodes are employed to lead the current out of the aluminum layer. The cell operates at a voltage varying from 5 to 7 volts and normally a current of 20,000 amperes is employed.

By anodic treatment in wet electrolytic cells aluminum may be given a tough, adherent and corrosion resistant surface of oxide which serves as a base for color and which is also finding use for protection of aluminum alloy aircraft structure from severe corrosion attack such as that of salt spray and sea-water. This development is still going forward rapidly and is expected to become of much greater importance in aluminum technology.

Electro-plating with aluminum on copper and other base metals has been accomplished by the use of a fused electrolyte of low melting point comprising the chlorides of aluminum and sodium. Tough, adherent, and non-porous deposits of pure aluminum are produced and many commercial uses will no doubt be found as the technique is improved.

Barium

Barium is one of the alkaline-earth elements and is characterized by great reactivity and interesting thermionic properties. It is produced by the electrolysis of fused barium salts and has been receiving considerable attention because certain of its alloys have useful thermionic properties. It has found commercial application in a nickel-base alloy for spark plug electrodes and has been of interest as an essential constituent of alloys intended for use as cathodes in thermionic devices. Such barium alloys are, in general, electric furnace products.

Beryllium

During the past few years the metal beryllium has received a great deal of attention, which has been primarily due to the results of systematic research both in this country and abroad. Beryllium may be produced by an electrolytic process which consists of the electrolysis of mixed beryllium oxyfluoride and barium fluoride. The only commercial ore of beryllium is a silicate of beryllium and aluminum. The beryllium oxide content of available ores lies between 6 and 12 per cent. The production of beryllium has been carried out both in this country and abroad.

The future of beryllium does not appear to lie in its use as a basic material, but rather as a minor constituent in more or less complex alloys.

About the only use thus far developed for the pure metal is as windows in X-ray tubes, inasmuch as beryllium is extremely transparent to X-rays. Experimental use in pistons and piston rings has been reported. Continued research will doubtlessly develop new uses for this interesting metal, inasmuch as it possesses a combination of high elastic modulus, low expansivity and lightness which is very attractive to many who are interested in mechanical developments. Its electrical resistivity is approximately 6.7 microhms per cu. cm. at room temperature.

Magnesium

This metal is produced by the electrolysis of molten magnesium chloride and more recently by means of processes in which magnesium oxide is dissolved in a bath of fused fluorides and decomposed by electrolysis to give the metal. The production of magnesium in the United States has increased from approximately 50,000 lb. in 1921 to more than 1,000,000 lb. in 1930. During 1930 magnesium forgings have appeared on the American market and with continued research it is expected that increased quantities of strong magnesium alloys in the form of castings and forgings will be rather extensively employed particularly in aircraft. With improved production technique purer metal is being produced and the susceptibility to corrosion lessened in consequence.

The outstanding difficulty in the way of increasing the use of magnesium has been the development of

suitable alloys and fabricating processes and great strides are being made in this direction.

Electrotechnology of Gases

The treatment of gaseous mixtures by electrical discharges in order to effect chemical reactions that would not ordinarily occur has received a great deal of attention. The work of Fischer and Peters in Germany is particularly interesting in that they find it possible to produce acetylene from methane with an energy consumption that compares favorably with that required by the conventional calcium carbide process. The cracking of heavy hydrocarbon vapors by corona discharge also shows some possibilities. A great deal of research is going on in connection with the chlorination of hydrocarbons such as methane, pentane, etc., and this promises a considerable expansion in the use of chlorine, which is an electrolytic product. Research investigations of the chemical effects of bombardment by high-speed electrons should also be mentioned.

Abrasives—Carborundum

Tungsten carbide cutting tools have found increasing application and this has necessitated the development of improved abrasive wheels for shaping them. As a consequence special grades of carborundum are being made, apparently of unusual purity, from which grinding wheels specially adapted to the shaping of carbide tools are made. Carborundum base resistors for high temperature electric heating furnaces have been considerably improved, and several manufacturers have designed about this type of resistor commercial furnaces for operating temperatures between 1,000 deg. and 1,400 deg. cent.

Aluminum silicate refractories of very high melting point are being fused in electric furnaces and cast into blocks and shapes for various purposes, particularly for parts for glass-melting furnaces. The melting and casting of such highly refractory substances is a new and interesting departure in industrial ceramic technology.

Cleaning of Metals

A wet electrolytic process for the removal of scale from metals which is said to be competitive with pickling and free from many of its objections has been put on a commercial basis. Hydrogen embrittlement is prevented by the automatic deposition of a thin film of lead on any area of clean metal as soon as it is exposed by scale removal. This lead film may be allowed to remain as a protection against corrosion or removed by anodic oxidation by reversal of the electrolyzing current.

Electrochemical Standards

The interest in our electrochemical standards for the international ampere and the international volt has been continued and during the coming summer cooperative measurements on these standards will be carried out at the Physikalisch-Technische Reichsanstalt. For this purpose Dr. G. W. Vinal, Chief, Section of Electrochemistry, U. S. Bureau of Standards and a member of this Committee is being sent to Germany. He will also make measurements at the Laboratoire Central d'Electricite in Paris, and the National Physical Laboratory in England.

Primary and Secondary Batteries

During the past year the American standard for dry cells has been revised and a new standard approved by the American Standards Association. This standard has been published by the Association and also by the Bureau of Standards as Circular No. 390. The technical requirements of the Government specifications are identical with those of the American standard, but the Government specification is being revised to accord with the form prescribed by the Federal Specifications Board for all Government specifications.

The Federal specifications for automotive storage batteries have been approved and published during the year. These are designated as W-B-131 and are contained in section 4, part 5 of the Federal Standard Stock Catalog.

The past twelve months have witnessed a considerable decline in the demand for primary battery products in general due to the business depression and the reduction in the number of battery operated radio sets in active use. This has naturally affected most the production of B batteries, though the production of 6-in. dry cells, many of which were also used for radio, has been seriously affected as well. The demand for flashlight batteries seems actually to be on the increase due perhaps to the appearance on the market of a rather wide variety and a considerable number of inexpensive flashlight cases which have apparently been widely bought.

The general decrease in demand for battery products has resulted in a tendency to reduce prices and on the part of at least the larger manufacturers to strengthen quality. Many of the smaller manufacturers have been forced out of the business as a natural consequence.

The year has brought the development of the industrial flashlight battery intended for use by public service corporations, railroads, theaters, and manufacturing organizations where the demand on the battery is considerably heavier than in ordinary flashlight use. At a recent conference at the Bureau of Standards two tests were standardized as representative of the industrial types of service and this has greatly facilitated and intelligently guided the development of satisfactory cells for this specific application.

Special radio B batteries of superior performance have been developed in response to demand created by radio-equipped automobiles for police squad use as well as for privately owned machines.

In the 6-in. dry cell group there has been a further advance in the life of the better telephone cells. Certain makes have reached the remarkably high figure of 360 days on the standard light intermittent test which

compares with a maximum of about 180 days ten years ago.

An interesting new development which has occurred in the primary battery field during the past year is the introduction by one manufacturer of an air depolarized portable caustic soda battery designed primarily for use as an A battery for specially designed radio receivers using the new two-volt tubes and operated entirely by batteries. It is hoped that radio receivers of this type will develop wide application in rural districts where power is not available for operating electric radio sets and where storage batteries cannot be conveniently charged. This so-called air cell radio A battery is said to be good for a year's average service with one of these receivers. The basis of its operation is the absorption by a porous carbon electrode of the oxygen from the air which is carried to the surface of the electrolyte where it acts as a depolarizer for the cell. While the principle employed is not a new one, its application to a portable practical battery is believed to be new.

During the year, the revised American Standard for Dry Cells has been published, both by the American Standards Association of 29 West 39th Street, New York City, and by the Bureau of Standards in its Circular No. 390.

In the field of storage batteries the recent publication of the Federal Specification for Automotive Batteries, designated as W-B-131, may be mentioned.

A new storage battery, the Drumm alkaline cell, which involves the use of an electrolyte of potassium hydroxide with electrodes of nickel and other substances not disclosed, is said to provide reduced weight, increased efficiency, and the possibility of recharging in a 30 minute period. The e. m. f. is 1.5 volts. Successful trials in heavy trucking service are reported from England.

Electric Melting Furnaces

The demand for better metallurgical performance of arc furnaces is bringing about refinements in control gear among which are the use of tap-changing transformers to enable more precise voltage control and a tendency toward the adoption of hydraulic drive for electrodes, in which pilot valves responsive to furnace current, voltage or kva. operate to control fluid flow to the electrode driving cylinders. More prompt response, improved sensitivity and absence of hunting are said to be provided by hydraulic operation.

Induction furnaces of the submerged ring type are finding somewhat wider application owing to improvements in refractories and in a few places abroad have been used on high-nickel alloys and for superheating cast iron for high-strength castings.

Coreless induction furnaces operating at high frequency have found commercial application in sizes up to two tons, with power ratings up to 600 kw. High-frequency generating units of 1,250 kw. are being built to supply 3½ ton furnaces. A common frequency is 980 cycles, but the trend is downward, particularly for large units. Commercial frequencies have been successfully applied and one manufacturer has successfully operated experimental four-ton units at 60 cycles, the entire kva. requirement being supplied by a motor-generator set. Considerable attention has been given to the technique of refining in these induction furnaces and some success has been attained.

Oxygen-free copper from large inductively heated furnaces is a commercial possibility of the near future. Such a material would avoid some of the weaknesses of present commercial copper and in particular its tendency to embrittlement when subject to hot reducing gases. Unusually high ductility may make it interesting for some mechanical uses.

Control of furnace atmosphere, vacuum melting, and the distillation of metals are all receiving attention at the hand of investigators.

Water Purification

Electrolytic purification of water has been receiving considerable attention following the announcement, in Germany, of a process and apparatus in which water is passed through a succession of diaphram type electrolytic cells which cause concentration of ionogens in the electrode compartments. It is susceptible of large-scale operation but so far has been used mainly to complete the purification of distilled water.

Sterilization of Milk

The electropure process of milk conditioning effects pasteurization by passing the raw milk rapidly between carbon electrodes where it is heated by the passage of 60-cycle current. This scheme enables refinements in the control of the time and temperature variables that have hitherto been impracticable and the quality and uniformity of the product are thereby enhanced.

Electrostatic Precipitation

The results of test of improved hot-cathode vacuum rectifiers indicate that it will be possible to improve the operation and decrease the physical dimensions of the electrical end of precipitation plant. Increased use of powdered coal firing has caused the ash which is carried up the stack to be troublesome and electrostatic precipitator equipment is finding application in this connection. The same fundamental ideas are being applied to the separation of suspended solids from liquids. The purification of insulating oils is a case in point and it is stated that by electrostatic cleaning higher breakdown values can be obtained than by methods now in general use.

Metal Powders

Finely divided metals find numerous uses in chemical technology and as pigment in the decorative arts. Electrolytic means have been developed for producing copper, tin, nickel, silver, and lead in crystalline form in sizes as fine as 500 mesh.

Miscellaneous Process and Plant

Mercury-Arc Rectifiers

There are under construction for a Canadian Plant mercury-arc rectifiers rated at 6,560 kw. each (10,000 amperes, 650 volts) to be used for the electrolytic production of hydrogen.

Rotary Converters

Another electro-chemical plant has installed synchronous converters with load ratio control type transformers to furnish direct current for an electrolytic process. These machines are rated at 5,440 kw. each (16,000 amperes, 340/370 volts). These machines are also of interest because of their use of volute housings as part of the ventilation system.

Electrodeposition of Tungsten

The electrodeposition of tungsten in the wet way from alkaline baths has been accomplished on a laboratory scale. Tungsten possesses such marked resistance to acid attack and to wear that this development may prove to be of considerable industrial importance.

Heat Treating Furnaces

A marked interest was shown by the steel industry in the use of electric furnaces for heat treatment service. One plant installed two 1,100-kw. resistor type furnaces 50 tons capacity each, one 1,000-kw. similar furnace, and other furnaces, making a total of 4,500 kw.

The use of artificial atmospheres in electric furnaces for heat treatment processes is making considerable progress. One steel plant has installed 2,000 kw. in furnace capacity for bright annealing of steel strip.

Electrically heated and controlled apparatus for controlling the composition of the gases used are coming into evidence.

The special requirements of the nitriding process which involves heating to approximately 550 deg. cent. articles of special alloy steel (containing small amounts of Cr, Al, Mo, and Ni) in an atmosphere of ammonia has led to the development of furnaces with special provisions for circulating the ammonia. Heat transfer is effected by forced convection instead of by radiation. It appears possible that the application of this principle will find extended application in special-purpose furnaces in which control of atmosphere is important.

In both the heat-treating and melting fields the refinements of metallurgical technique and the growing recognition of the value of high quality and uniformity of product have brought about such profound changes in the design and operation of furnaces that they are coming to resemble machine tools rather than the piles of brick that the word usually calls to mind.

Conclusions

It is believed that this report reflects the more important trends in electrical process technology and hoped that it may draw the attention of electrically trained men to the very interesting possibilities in the field of the development of processes and materials dependent upon the forces that only electricity can bring into play.

The Chairman wishes to acknowledge the assistance given by members of the Committee and by numerous individuals in the preparation of this report which is respectfully submitted on behalf of the Committee on Electrochemistry and Electrometallurgy.

Electrophysics

ANNUAL REPORT OF THE COMMITTEE ON ELECTROPHYSICS*

THE annual report of the Committee on Electrophysics has generally taken the form of an account of the progress in the field of electrophysics during the preceding year. In view of the steady increase of the activity in this field the matter to be covered has increased greatly, and the report for the year 1929-1930 was a lengthy one in spite of all efforts to keep its size down to a minimum.

At a meeting of the committee held January 30, 1931 its field of activity and in particular its annual report were discussed at considerable length. It was the sense of the committee that it was one of the most important of its functions to bring to the attention of electrical engineers the progress being made in electrophysics. It was felt very strongly, however, that this cannot be done in the best possible fashion by reporting the progress for a year at one time and publishing it as a unit. Accordingly, the committee decided that it could be of much greater service to the engineering profession if its reviews of the progress in electrophysics were published from time to time by subjects instead of annually as a unit. As a result the plan was adopted of publishing reviews of the progress of electrophysics by subjects in ELECTRICAL ENGINEERING. Each contribution will aim to cover the progress in its particular field from the date of the preceding report as nearly up to the date of publication as is possible. A tentative schedule of the proposed subjects is as follows:

Magnetism and Magnetic Materials.
Propagation of Electric Waves.
Electric Discharges in Gases.
Dielectrics.
Thermionics and Photoelectricity.
Vacuum Gas Discharge and Photoelectric Tubes.
Electric Conduction in Solids.
Electromagnetic Theory.

In addition the Committee plans to sponsor from time to time for publication in ELECTRICAL ENGINEERING papers by recognized authorities on various subjects in electrophysics of interest to electrical engineers. One such paper is published herewith. After all the reviews for any one year have been published, they may be collected and published together in the TRANSACTIONS if it should be considered desirable.

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Oliver E. Buckley, Chairman.
V. Bush, W. B. Kouwenhoven, Leigh Page,
W. G. Cady, G. M. J. Mackay, W. S. Rodman,
W. F. Davidson, K. B. McEachron, J. Slepian,
C. L. Fortescue, L. W. McKeehan, W. F. G. Swann.
W. S. Gorton, H. Nyquist,

Magnetism and Magnetic Materials

The following review of progress in magnetism and magnetic materials covers the period since the last report of the Electrophysics Committee. The progress in other phases of electrophysics will be covered similarly in succeeding reviews. The Committee also may offer from time to time papers on subjects in electrophysics of interest to electrical engineers.

MAGNETISM

Our understanding of ferromagnetism has advanced during the period since our last report (JL. A. I. E. E. **49**, 721, 1930) in several important respects. Heisenberg's interaction theory, which refers the stability of magnetization to the low potential energy of codirected electron spins in neighboring atoms, has been applied by Powell (*Proc. Phys. Soc.* **42**, 390, 1930) to explain the change in dimensions which take place when iron and nickel lose their ferromagnetism on heating. This change, a decrease in the case of iron, an increase in the case of nickel, is isotropic, being thus wholly unlike the principal part of magnetostriction which differs greatly in different crystallographic directions. It is concluded from the fact that both signs of change occur that some account must be taken, at least in the case of iron and probably in all cases, of atoms more remote than the immediate neighbors. Becker and Kirsten (*Zeitsch. f. Physik* **64**, 660, 1930) who identify the stabilizing forces with internal elastic strains, have succeeded in getting rather good agreement between the permeability of highly stressed nickel as measured and as calculated from limiting magnetostriction and the elastic moduli. Rankin (*J. Roy. Tech. Coll.* Glasgow **2**, 385, 1931) has continued his experiments on magnetostriction in overstrained metals. Akulov has continued his discussions of the relations between magnetostriction, magneto-resistance and elasticity concluding in his latest papers (*Zeitsch. f. Physik* **67**, 794, 1931; *Phys. Zeits.* **32**, 107, 1931) that the magnetic behavior of single crystals is fully explained by a dual process of reversals and rotations of the magnetic elements and that the magnetic properties of polycrystalline metal *without large scale anisotropy* can be calculated from data obtained for monocrystals. McKeehan (*Rev. Mod. Phys.* **2**, 477, 1930; **3**, 190, 1931) has reviewed the content and relations between the current theories of ferromagnetism and some of the recent experimental evidence pertinent thereto.

Several papers, in addition to that of Powell, already referred to, deal with the experimental and theoretical

aspects of the Curie point. Tyler (*Phil. Mag.* [7] **11**, 596, 1931) shows that the decrease of apparent saturation values with rise of temperature is practically according to the same law for iron, cobalt, and nickel, and that this is consistent with the idea that in all three metals single spinning electrons are free to change their axial direction, although in all these cases the average number of such magnetizable electrons per atom is greater than one. According to these data, therefore the ferromagnetic unit is sub-atomic rather than atomic. Above the Curie point it appears (Stoner, *Phil. Mag.* [7] **10**, 27, 1930) that atoms begin to act as units. Forrer and Hoffmann (*Comptes Rendus* **191**, 1046, 1930) present new evidence for a doubling of the (ferromagnetic) Curie point in nickel, the coercive force first decreasing, then increasing, and finally decreasing again as the temperature rises. An apparent disagreement between two experimenters, Weiss and Bates, in regard to the temperature at which the specific heat anomaly becomes greatest as the Curie point is approached has been dissolved by new evidence. Bates (*Proc. Phys. Soc.* **42**, 441, 1930; **43**, 87, 1931) now also finds this temperature to be where $-d\,I^2/d\,T$ is maximum; his earlier experiments were vitiated by an irreversible change in the properties of his material (manganese arsenide) produced by the small rise in temperature (magneto-caloric effect) associated with applying the magnetizing field. Incidentally, the specific heat anomaly is here far too large to be ascribed to an elementary magnet like that in iron or nickel.

The anomalous temperature coefficient of electrical resistance for ferromagnetics near their Curie points is closely associated with their magnetizability. Gerlach (*Zeitsch. f. Physik* **59**, 847, 1930; *Ann. der Physik* [5] **6**, 772, 1930) and Borelius (*Ann. der Physik* [5] **8**, 261, 1931) present opposing opinions regarding the anomaly. The former in agreement with earlier work of Cabrera regards the high-temperature state (above the Curie point) as normal and the low-temperature state as possessing an abnormally low resistance, the latter supports the contrary view that it is the low-temperature or completely magnetized state which has normal resistance. The transition as the Curie Point is approached from below is the same whichever view is taken.

The closely related subject of heat production during magnetization and demagnetization has been examined in a preliminary way by Gilbert (*Comptes Rendus* **191**, 1309, 1930) who finds no cooling in cobalt steel at H up to 18,000 except that attributable to the magneto-caloric effect of Weiss. The more complete report of Ellwood's results (*Phys. Rev.* [2] **36**, 1066, 1930) confirms his earlier finding of a cooling in carbon steel at low values of H on the ascending branch of a loop, and announces a second stage of cooling at moderate values of H. It should be noted that the magneto-caloric effect would account only for a minute heating in this part of the loop.

An effort has been made by Bitter (*Phys. Rev.* [2] **37**, 91, 1931) to coordinate ferromagnetic behavior with the small scale imperfection of metallic crystals recently predicted by Zwicky (*Helvetica Physica Acta* **3**, 269, 466, 1930; **4**, 49, 1931). Frenkel and Dorfman (*Nature* **126**, 274, 1930) deal with the same problem on purely thermodynamic principles, deciding that a large crystal cannot act as a magnetic unit.

Experiments on the Barkhausen effect in a rotating magnetic field (Cisman, *Ann. der Physik* [5] **6**, 825, 1930), make it more plausible than ever to suppose that the occurrence of a discontinuity in magnetization requires a definite degree of divergence between the applied field and the local magnetization. There is, in fact, a decided parallelism between Cisman's Barkhausen effects and hysteresis in rotating fields, most recently studied by Seiyama (*Mem. Kyushu Univ. Coll. Engg.* **5**, 227, 1930). Heaps and Bryan (*Phys. Rev.* [2] **36**, 326, 1930) have shown that large changes in magnetization and in magnetostriction are simultaneous. Bozorth has just discovered (*Nature* **127**, xxx, 1931) that in a very slowly changing magnetic field the Barkhausen discontinuities which can be detected by a high-speed oscillograph occur in closely grouped sets with quiet intervals between them. These compound events, in proximate analysis, can easily be mistaken for single events. This apparently explains the wide disagreement between published statements as to the volume of metal affected in a single discontinuity. The time required for the spreading of a major magnetic disturbance has been studied by Sixtus and Tonks (*Phys. Rev.* [2] **36**, 1441, 1930).

The gyromagnetic effect, hitherto only observed in ferromagnetic materials—most recently by Barnett (*Phys. Rev.* [2] **36**, 789, 1930)—has now been measured for a paramagnetic material by Sucksmith (*Proc. Roy. Soc.* [*A*] **128**, 276, 1930; *Proc. Phys. Soc.* **42**, 385, 1930). The phenomenon is merely easier to observe in ferromagnetics on account of their easier magnetization.

In studies on diamagnetic and weakly paramagnetic metals the theory has been improved by Landau (*Zeitsch. f. Physik* **64**, 629, 1930) and Teller (*Zeitsch. f. Physik* **67**, 311, 1931) so that better predictions are now possible as to the diamagnetism to be expected from conduction electrons. On the experimental side relatively enormous changes in susceptibility—much larger than the changes in conductivity make probable—have been reported by Honda and Shimizu (*Nature* **126**, 990, 1927) and by Bitter (*Phys. Rev.* [2] **36**, 978, 1930), both of whom measured the susceptibility of copper as affected by cold work and annealing. Banta (*Phys. Rev.* [2] **37**, 634, 1931) has attempted without success to duplicate Bitter's findings.

Spectroscopic evidence that some atomic nuclei have a small magnetic moment continues to accumulate (Fermi, *Zeitsch. f. Physik* **60**, 320, 1930; Goudsmit and Young, *Phys. Rev.* [2] **35**, 1418, 1930; Frisch and Ferchmin, *Naturwiss*, **18**, 866, 1930). The effect upon gross magnetic properties of such nuclear magnetic

moments as have yet been shown to exist must be very small.

Effects of magnetic fields on electrical resistance and electric potential with or without the presence of thermal currents and temperature differences have been reviewed on the basis of the new electron theory of metals by Sommerfeld and Frank (*Rev. Mod. Phys.* **3**, 1, 1931). The proper mode of description of these galvanoelectric, thermoelectric, galvanomagnetic and thermomagnetic effects have been discussed by Perrier (*Helvetica Physica Acta* **3**, 317, 400, 1930). The conditions are especially complicated in the case of ferromagnetics. Pugh (*Phys. Rev.* [2] **36**, 1503, 1930) has shown for iron that the magnetization, I, or the ferromagnetic induction, B-H, is more important than either H or B in fixing the magnitude of the Hall e. m. f. Stierstadt (*Zeitsch. f. Physik* **65**, 575, 1930; **67**, 725, 1931) has studied magneto-resistance in electrolytic iron for both longitudinal and transverse magnetizations. Williams and Sanderson (*Phys. Rev.* [2] **37**, 309, 1931) present new data on magneto-resistance in nickel strips of different mechanical history.

The magneto-resistance of bismuth single crystals at extremely low temperatures, below 20 deg. K, has been studied in detail by Schubnikow and de Haas (*Nature* **126**, 500, 1930; *Proc. Amsterdam Acad.* **33**, 363, 418, 1930), who find a whole series of unexpected phenomena. Unlike the magneto-resistance at higher temperatures the relative change in resistance is no longer a smoothly varying function of the applied field, H, nor of the azimuth in any crystallographic plane yet examined. At higher temperatures, however, theory has caught up with experiment, for Frank (*Zeitsch. f. Physik* **64**, 650, 1930) has shown that the straightening out of $\Delta R/R$ *vs.* H curves at high H values, first observed by Kapitza, is completely accounted for by the quantum theory of electronic conduction. The parabolic increase of $\Delta R/R$, formerly supposed to be called for by the theory, is only possible for relatively limited ranges in H.

One of the most puzzling experimental results recently published is that of Allison and Murphy (*Am. Chem. Soc. Jl.*, **52**, 3796, 1930), who report that the magnetic double refraction (Faraday Effect) in certain solutions is characteristic, not only of the elements present but even of the number of isotopes of each, and furnishes a highly sensitive means for chemical analysis.

In the domain of magnetometry Sanford has been investigating magnetic permeameters, particularly those for use at high inductions (*Bu. Std. J. Res.* **4**, 177, 703, 1930; **6**, 355, 1931). A new level of precision in magnetic curve tracing has been attained by Haworth (*Bell System Tech. Jl.* **10**, 20, 1931; *Rev. Scient. Instr.* [N. S.] **2**, 125, 1931) who compensates the torque of a fluxmeter suspension by a photoelectric current depending upon the momentary deflection. Brüche (*Zeitsch. f. tech. Physik* **12**, 94, 1931) has considerably refined the methods for exploring magnetic fields by narrow beams of cathode rays. Freed and Kasper (*Phys. Rev.* [2] **36**, 1002, 1930) have improved the accuracy of Gouy's method for measuring the susceptibility of weakly magnetic solutions.

A stimulating book by S. R. Williams[1] gives a readable account of the experimental side of the subject of magnetism, with especial emphasis on ferromagnetism.

An important announcement regarding magnetic units as adopted by the International Electrotechnical Commission was made by Dr. Kennelly at the Winter Convention in New York. The electrophysics committee is by no means unanimously in accord with the suggestions of the international body. Some of our members feel that the already existing confusion in regard to the physical significance of B and H is increased rather than diminished by giving physical dimensions to their ratio. It is interesting to notice that a body of German engineers went even farther than the I. E. C. in the effort to rationalize empirical relations (*Elektrotech. u. Maschinenbau* **48**, 950, 1930).

Magnetic Materials

The results of many investigations carried out in the past three or four years confirm the view that crystal grain size is one of the important factors in magnetic materials. Yensen (*Metals and Alloys*, **1**, 493-495; 1930) has proposed an expression for the hysteresis loss in iron in terms of the crystal grain size and impurities in the metal, leading to the conclusion that for perfect single crystals, free from impurities and internal strain, the hysteresis loss vanishes. Gerlach has more recently arrived at a similar conclusion. (*Zeitsch. f. Physik*, **64**, 502-506; 1930). On the other hand Von Auwers and Sizoo (*Zeitsch. f. Physik*, **60**, 576-580; 1930) conclude that crystal grain size has much less influence on remanence than on hysteresis loss and coercive force.

What promises to be of great importance is the announcement by Cioffi (*Nature*, **126**, 200-201; 1930) that ordinary polycrystalline iron may be made to acquire very high permeability by heat treating at high temperature in hydrogen. The reported initial and maximum permeabilities are 6,000 and 130,000, respectively, and the coercive force and hysteresis loss are respectively 0.05 gauss and 300 ergs/cu. cm./cycle, for $B_m = 14{,}000$. Later unpublished values give 180,000 for the maximum permeability, 0.025 gauss for the coercive force and 190 ergs/cu. cm./cycle for the hysteresis loss for the same maximum induction. These properties are ascribed partly to purification of the iron and partly to the hydrogen actually absorbed in the metal. Further correlation appears to be necessary between crystal grain size and magnetic properties in view of these results, since the grain size of this material appears to be of little importance.

The existence of the A_3 point in carefully purified iron occurring reversibly between 907 deg. cent. and

1. "Magnetic Phenomena," McGraw-Hill, 1931.

910 deg. cent. has been confirmed by Roberts and Davey (*Metals and Alloys* **1**, 648-654; 1930), by X-ray crystallographic determinations. This fact has recently been a matter of some dispute (Yensen, A. I. M. & M. E., *Inst. Metals Div.*, 320-332; disc. 332-349; 1929).

The increasing importance of nitrided steels has led to further investigations of the iron-nitrogen system. Qualitative and quantitative measurements by Lehrer (*Zeitschr. f. Electrochem.*, **36**, 460-473; 1930) by means of magnetization-temperature curves have been used to construct the equilibrium diagram for the iron-nitrogen system. The results show that up to 11 per cent nitrogen there are four phases, in agreement with the X-ray determinations of Hägg (*Zeitsch. f. Physik. Chem.* **8**, 455-474; 1930) and Eisenhut and Kaupp (*Zeitschr. f. Electrochem.* **36**, 392-404; 1930). Kö.ter (*Archiv. f. Eisenhüttenwesen* **3**, 637-648; 1930) has shown that nitrogen in α-iron remains in supersaturated solution even after slow cooling, requiring prolonged heating at low temperatures for complete separation, with a resultant increase in conductivity and increase in coercive force from 4 to 7 gauss. The segregation of nitrogen in the supersaturated solution is further accelerated by cold working (*Archiv f. Eisenhüttenwesen*, **3**, 649-658; 1930).

A number of alloys of iron and non-magnetic elements has been investigated. Pure electrolytic iron having a trace of phosphorus has been found to have better magnetic properties than commercial silicon steel. (*Gayler, Metallwirtschaft*, **9**, 677-679; 1930.) The iron-silicon system has been studied by Haughton and Becker, (*Iron and Steel Inst. Jl.*, **121**, 315-335; 1930) using metals of higher purity than heretofore. The existence of phases corresponding to the compounds FeSi, and Fe_3Si_2 have been confirmed, and in addition a phase which is probably the compound Fe_2Si_5. The addition of 14.5 per cent silicon lowers the Curie point of iron to 490 deg. cent. A magnetic transformation point occurring at 82 deg. cent. in the Fe_3Si_2 phase confirms the earlier work of Murakami (*Tohoku Imp. Univ. Sci. Rep.*, **10**, 79-92, 1921). Oya (*Tohoku Imp. Univ. Sci. Rep.* **19**, 235-245; 1930) has found that additions of vanadium to iron first raise the Curie point then depress it, so that it is room temperature for 35 per cent vanadium. The alloys of iron and chromium with approximately 18 per cent chromium have been found to have zero magnetostriction (Dean, *Rensselaer Polytech. Inst. Bull. No. 26*, Eng. and Sci. Series; 1930). Fischer (*Rensselaer Polytech. Inst. Bull. No. 28*, Eng. & Sci. Series; 1930) has found that this range of alloys has higher permeability and is less sensitive to quenching strains than other alloys of this group. This behavior has already been observed in permalloy (Buckley and McKeehan, **26**, 261-273; 1925) and is in accordance with McKeehan's theory of magnetostriction (*Phys. Rev.* **28**, 158-166; 1926). Kussmann, Scharnow, and Messkin (*Stahl u. Eisen*, **50**, 1194-1197; 1930) have found that additions of copper up to 0.7 per cent increase the resistance of iron to corrosion without impairing its magnetic and electrical properties. A general deterioration of these properties is obtained for higher copper concentrations.

The relation of magnetic properties to mechanical hardness has been investigated by Messkin (*Stahl u. Eisen*, **50**, 105-106; 1930) who has found that cold rolling increases the remanence and coercive force of carbon steel; and by Herbert (*Proc. Roy. Soc.*, **130**, 514-523; 1930) who has observed age hardening of steel and non-magnetic metals subjected to a changing magnetic field.

Sachse and Hasse have found that (*Zeitsch. f. Physik Chem.*, [A] **148**, 401-412; 1930) regular crystals of ferromagnetic ferric oxide, Fe_2O_3, are unstable at all temperatures, the susceptibility falling by 60 per cent in 4 years at room temperature. The fact that ferric oxide has 10^{-10} the conductivity of the ferromagnetic metals, leads Sachse (*Zeitsch. f. Phys. Chem.*, [B] **9**, 83-91; 1930) to conclude that free electrons cannot be concerned in its magnetic properties. The ferrites of magnesium, lead, copper, and nickel are also ferromagnetic at ordinary temperatures, cadmium ferrite being sometimes ferromagnetic and sometimes paramagnetic (Holgersson and Serres, *Comptes Rendus*, **191**, 35-37; 1930). In mixtures of Fe_2O_3, NiO, and C_0O, Veil (*Comptes Rendus*, **190**, 181-183; 1930) has found a higher coefficient of magnetization for the composition represented by $(Fe_2O_3)_2\,NiOC_0O$.

A somewhat higher Curie point has been obtained for nickel by Jordan and Swanger (*Bur. Std. Jl. of Res.* **5**, 1291-1307; 1930) which is believed to be due to the greater purity of their nickel specimen. Sadron has found that (*Comptes Rendus*, **190**, 1339-1340; 1930) small additions of chromium to nickel, causes the saturation value at absolute zero to diminish linearly with chromium content, the Curie point for an alloy with 12 per cent Cr being absolute zero.

Widespread interest in the nickel-iron alloys coming under the collective name of permalloy is indicated by its numerous modifications to meet specific needs. Elmen has obtained very high initial permeability and resistivity in nickel-iron alloys by additions of molybdenum, chromium or tungsten (U. S. Pat. 1,757,178; *Jl. Frank. Inst.* **207**, 583-618; 1929). Stäblein (U. S. Pat. 1,760,326) has obtained high resistivity by additions of silicon. Bandur (U. S. Pat. 1,743,089) and Yensen (*Elec. Jl.* **27**, 214-218; 1930) report that with suitable heat treatment some nickel-iron alloys may be made to acquire sensibly constant permeability over a limited range of induction. Similarly, Smith and Garnett (U. S. Pat. 1,746,500) have obtained substantially constant permeability in nickel-iron alloys by additions of copper. Also, Gumlich, Steinhaus, Kussmann and Scharnow (*E. N. T.*, **7**, 231-235; 1930) report that high resistivity and small variation of permeability with magnetizing force are obtained in nickel-iron alloys by small additions of manganese.

Von Auwers, (*Wiss. Veroffentlich Siemens-Konzern* **9**, 262-293; 1930) has studied the effect of strain on the

magnetic properties of permalloy. The results of numerous experiments indicate that the properties of permalloy cannot be accounted for on the basis of strain alone.

Methods of design and testing of permanent magnets have kept abreast with the improvements in magnetic properties. Elenbaas (*Physica*, **10**, 273-286; 1930) has derived a formula for calculating the field intensity in a toroid with an air-gap, based on the assumption that the demagnetization curve is an ellipse; this should prove useful in the design of permanent magnets. It is well known that the magnetization of a ferromagnetic material by a steady field is considerably increased by the superposition of an alternating field. Schrankow and Janowsky (*Zeitsch. f. tech. Physik* **11**, 429-432, 1930) apply this method of bringing permanent magnets to high inductions. An accurate method of testing bent permanent magnets has been described by Webb and Ford (*I. E. E. Jl.*, **68**, 773-778; 1930) whereby both B and H are measured by means of search coils and a ballistic galvanometer. The superior properties of cobalt-steel as permanent magnets have found application in the magnetic compass for aircraft, disturbances from stray magnetic fields being avoided by shielding with hipernik, a nickel-iron alloy of high permeability (J. R. Gier, *Elec. Jl.*, **27**, 114-115; 1930).

The need for accurate and constant substandards of frequency has stimulated further work on vacuum tube oscillators controlled by the resonant magnetostrictive vibrations of magnetic materials. This method of control requires the use of materials which have good magnetostrictive properties and small temperature coefficients of permeability and expansion. Vincent (*Proc. Phys. Soc.* **43**, 157-165; 1931) has extended the range of the magnetostriction oscillator of Pierce, (*Proc. Am. Acad. Sci.*, **63**, 1-47; 1928) to radio frequencies by using corronil, a nickel-copper-manganese alloy, and glowray, a nickel-iron-chromium alloy (*Proc. Phys. Soc.* **41**, 476-486; 1929); the latter, particularly, has a high degree of stability. Smith (*Proc. Phys. Soc.* **42**, 181-189; 1930) has determined the nature and magnitude of the coupling between the mechanical vibrator and the electric circuit for a toroidal specimen of a nickel-iron alloy vibrating radially in its fundamental mode. Muzzey (*Phys. Rev.* **36**, 935-947; 1930) has used the magnetostriction oscillator as a means of exciting cylinders of stainless steel in studying the dependency of frequency of vibration on length and diameter of the cylinders.

ACKNOWLEDGMENT

The Committee is indebted to Professor L. W. McKeehan, of its membership, and to Mr. P. P. Cioffi for material for this report.

General Power Applications

ANNUAL REPORT OF COMMITTEE ON GENERAL POWER APPLICATIONS*

THE principal activity of the Committee during the past year has been in arranging and carrying out of plans for the Industrial Session held at the Winter Convention. As this Committee is interested in the application of electricity to all industries which are not specifically covered by other committees of the Institute, it was agreed that papers to be of interest to the greatest number of engineers should be of a general nature and not confined to a specific industry or application. The papers presented were consequently arranged and prepared with this thought in mind. During this period of industrial depression an increasing amount of attention is being given to the subject of reducing manufacturing costs and it was hoped that industrial engineers would find in these papers various ideas which could be applied to their own problems.

Industrial Papers Presented

Besides those papers presented at the Winter Convention several other papers of an industrial nature were presented at district meetings. Following is a list of those papers which have come to our attention:

Philadelphia Meeting Oct. 13 to 15, 1930:

Air Conditioning in Industry, by A. H. Clogston of the Cooling and Air Conditioning Corp.

A New System of Speed Control—A-C. Motor-Driven Power Station Auxiliaries, by A. M. Rossman of Sargent and Lundy, Inc.

Louisville Meeting, Nov. 19 to 22, 1930:

Electricity in the Cement Industry, by R. H. Rogers of the General Electric Company.

Electric Power in the Lumber Industry, by A. H. Onstad of Weyerhaeuser Timber Co.

Winter Convention, January 26 to 30, 1931:

Electron Tubes in Industry, by W. R. King of General Electric Co.

Automatic Regulators in Industry, by J. H. Ashbaugh, Westinghouse Electric and Manufacturing Co.

Electrical Distribution Systems for Industrial Plants, by W. J. McClain, of Louis T. Klauder Co.

The Synchronous Motor with Phase-Connected Damper Winding as a Drive for High-Torque Loads, by M. A. Hyde, Jr., Westinghouse Electric and Manufacturing Co.

The Design and Application of Synchronous Motors to Meet Special Requirements, by D. W. McLenegan and A. G. Ferriss of General Electric Co.

Pittsburgh Meeting, March 11 to 13, 1931:

Conversion and Distribution of General Purpose D-C. Power in Large Industrial Plants, by R. D. Abbiss, Carnegie Steel Co. and D. C. West, Westinghouse Electric and Manufacturing Co.

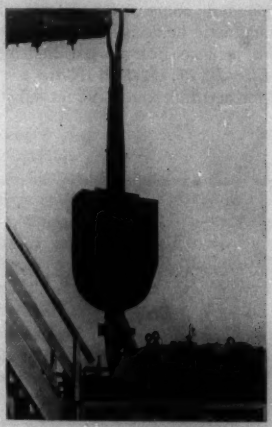

Fig. 1—Combination Pumping Unit for Oil Wells Including Motor, Gears, and Control

Symposium on *Interconnection Between Utilities and Industries*. Several papers.

The Use of Electricity in Large Annealing Furnaces, by J. C. Woodson, Westinghouse Electric and Manufacturing Co.

A Modern Electrified Dairy Plant, by A. J. Dreux, Reick-McJunkin Dairy Co. and H. C. Brunner, Westinghouse Electric and Manufacturing Co.

Review of Industrial Progress

Since the past year has not been one of great industrial development or activity, it is felt that this report

*COMMITTEE ON GENERAL POWER APPLICATIONS:

C. W. Drake, Chairman,
E. A. Armstrong, James Clark, Jr., J. F. Gaskill, Clyde D. Gray, John Grotzinger, Fraser Jeffrey, A. M. MacCutcheon, H. A. Maxfield, John Morse, N. L. Mortensen, A. M. Perry, D. M. Petty, F. O. Prior, H. W. Rogers, L. D. Rowell, M. R. Woodward.

should include not only a review of the major industrial developments but also should indicate the trend of development along both application and apparatus lines in industry.

Petroleum Industry

During the past year pipe-line transportation of liquid fuel over long distances has been extended to

Fig. 2—Portable Diesel Engine-Driven Set for Variable Voltage Oil Well Drilling Outfits (Shop View)

include gasoline. Electric pumping stations supplied with central station service, are increasing in number and proving their economy. The latest development is an electric station with three 800-hp. pumping units which is completely controlled from a dispatching office about 15 miles away. This is the Sand Springs Station of the Texas Empire Pipe Line that connects Oklahoma oil fields with the Chicago refineries. The

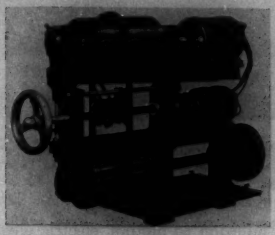

Fig. 3—Selsyn Generator and Cone Pulleys for Sectional Paper Machine Drive

supervisory control permits the dispatcher to exercise complete control over the station and gives a visual indication of its operation. The dispatcher can tell at a glance what units are operating, what the intake and discharge pressures are and as much other pertinent information as could be obtained if the operator were in the station. In case of trouble the equipment is shut down automatically and the dispatcher advised of the nature of the trouble.

Development in electrical oil field pumping and drilling equipment has been towards the use of combination, or factory assembled apparatus which eliminates many parts and reduces the installation expense in the field. One of the latest pumping units consists of a combination of gear, motor, and control built in one unit. The equipment is weatherproof and requires no housing. The unit is also provided with change gears for obtaining several speeds as required for various pumping conditions.

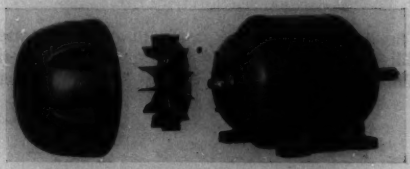

Fig. 4—Totally Enclosed Fan-Cooled Motor with Fan and Fan Casing Removed

During the past year several variable voltage d-c. oil well rotary drilling outfits have been built and put in service, using Diesel engines as prime movers. These outfits are being used primarily on locations where central station power is not available. The ease and simplicity of control obtainable with the variable voltage d-c. system, its low energy requirement and flexible operating characteristics, make this system very desirable for this type of oil service.

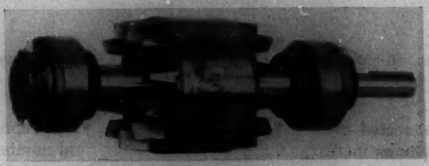

Fig. 5—Induction Motor Rotor Showing Cartridge Type Ball-Bearing Housings

Two installations are also reported where standard a-c. drilling equipments were installed and supplied with power from Diesel engine-driven generators, and, although this system may lack some of the desirable features of the variable voltage system, it makes it possible to use standard a-c. motors for pumping and other uses.

Pulp and Paper Industry

Sectional paper machine drives were installed during the year on a wide variety of machines from low-speed cylinder to high-speed fourdrinier and the use of section regulators of the carbon pile type instead of the contact

making type was quite noticeable. A description of some of these carbon pile regulators is given in Mr. Ashbaugh's paper, presented at the Winter Convention.

A regulator for sectional drives using Selsyn equipment so that the main regulating equipment may be mounted remote from the paper machine has been placed in operation during the year. At the paper machine, in connection with each sectional motor, is a Selsyn generator driven through suitable cone pulleys which provide necessary speed adjustment or "draw" between the various sections. The resistance elements of the regulator are of the carbon pile type.

Rural Electrification

The use of electricity on the farm has increased rapidly during the past year and reports from central stations indicate that approximately 90,000 farms were connected to their lines during the year. This represents an increase of 16 per cent over the total number previously connected. This growth is accounted for partly by the interest of the power companies in the farm load and partly by improved rate structures and power schedules. But of fully as great importance however is the increasing list of electrical equipment which is available and specially adapted for farm service. The attention being given to the production of milk with a low bacteria count has done much to force the installation of dairy sterilizing and dairy refrigerating equipment and these devices in connection with other dairy and household equipment make a very desirable electrical load.

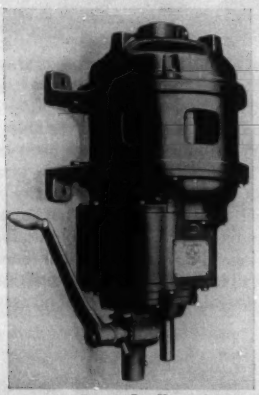

Fig. 6—Motor with Built-In Four-Speed Transmission Showing Speed Changing Lever

Engineering research and investigation have proven the possibility of using 5-hp. electric motors for practically all stationary work such as silo filling, feed grinding, wood sawing, etc., instead of using 15- or 20-hp. tractors. Numerous improvements have recently been made in the design and construction of portable motor equipment for such service which includes automatic linestarters with thermal overload protection, effective methods of belt tightening, and other desirable features.

Food Products Industry

Although this industry has received but little attention from electrical engineers, it is the fourth greatest user of electric motors on the basis of connected horsepower. In addition to motors, electric energy is used for various other purposes as the production of ultraviolet rays to help preserve or increase the vitamin content of foods; photoelectric tubes for actuating operations of wrapping, sorting, and counting; cooking of foods by various electrical processes, and the pasteurization of milk.

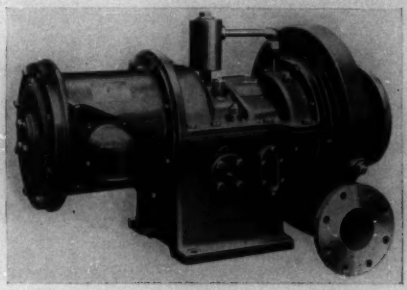

Fig. 7—Geared Centrifugal Refrigeration Compressor Driven by Totally-Enclosed Induction Motor

Fig. 8—300-Hp. 164-Rev. per Min. Synchronous Motor of the Phase-Connected Damper Type as Installed in a Cement Plant

A paper on the subject of *A Modern Electrified Dairy Plant* was presented at the Pittsburgh District Meeting of the Institute March 11-13, 1931, by Mr. A. J. Dreux and Mr. H. C. Brunner. This paper

illustrates how a modern electrified dairy offers a very desirable type of load for central stations, particularly when using the electrical conductivity method of pasteurization.

Induction and D-C. Motors

During the past year several new lines of induction motors have been placed on the market and the trend is toward simplification and standardization of design. The greater use of standardized parts reduces the stocks which must be carried both by the user and manufacturer, increases the number of combinations or types of motors possible with a given number of parts and in general makes the apparatus more universally adaptable.

Several new lines of totally enclosed fan-cooled squirrel-cage induction motors have been announced and in practically all cases these motors are on the same frame size as corresponding ratings of open motors. In these fan-cooled motors ball or roller bearings are used almost without exception and the cartridge type of bearing housing is quite generally adopted. This construction permits the dismantling of the motor and the removal of the rotor without exposing the bearings.

Fig. 9—Special Synchronous Motor with External Revolving Field, Direct Connected to Gyratory Crusher

A number of manufacturers has also brought out lines of totally enclosed fan-cooled motors for use in locations where explosive gases are present. These motors are approved by the Underwriters Laboratory for use in gasoline refining, garages, gasoline handling, and filling stations, dry cleaning establishments, chemical plants, paint factories, and in similar locations.

To meet the requirements of testing large vertical pumps and turbine wheels a vertical dynamometer rated at 300 hp. has been developed. The stator is supported in such a manner that it is free to rotate and the torque developed is measured on a beam and dial scale. The direct-current armature is especially constructed and makes use of a shrink-ring type commutator for high-speed operation.

Fractional horsepower motors of the universal commutator type have a wide speed range from no load to full load and consequently are not generally applicable for the constant speed service. A novel type of clutch has been developed which when installed in these fractional horsepower motors maintains a practically constant speed at the coupling regardless of how much higher the motor speed may go. This device consequently makes it possible to use universal motors for such applications as cash registers, calculating machines, small motor-generator sets, etc.

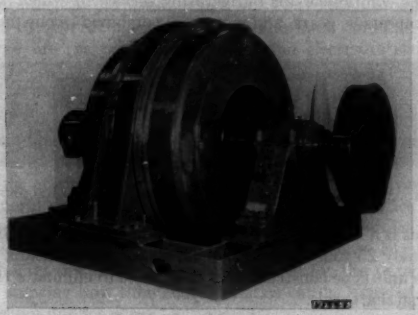

Fig. 10—250-Hp., 450-Rev. per Min. Totally-Enclosed Fan-Cooled, Synchronous Motor

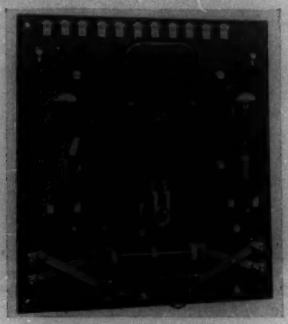

Fig. 11—Electronic Tube Control for Small D-C. Motors

Although speed reducers or gear reducers are now extensively used there is a decided trend towards the combination of various types of these gear reducers with industrial motors in order to form a more compact and self-contained unit. Some of these are of the fixed ratio type with either single, double, or triple reduction while

others have a variable ratio. A recent addition consists of a standard constant speed motor in combination with a 4-speed gear forming a self-contained and very compact unit. With this combination various gear ratios are available and it is possible to change from one speed to another under full load conditions.

Another example of a combined unit is a centrifugal type compressor for refrigerating service in which the compressor, gears, and motor are combined in one unit.

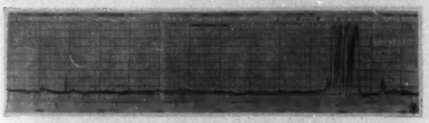

FIG. 12—SAMPLE CHART OBTAINED WITH SMOKE RECORDER

This is a high-speed single-stage compressor of approximately 25 tons refrigeration capacity and by means of the unit type construction it is possible to eliminate the usual shaft seals.

A paper presented by Mr. A. M. Rossman at the Philadelphia meeting *A New System of Speed Control for A-C. Motors*, gives a detailed account of a new method of speed control, its possibilities, and savings. The system consists essentially of a constant speed a-c.

FIG. 13—CONSOLE TYPE BOARD FOR ELECTRONIC TUBE CONTROL OF THEATER LIGHTING AND DIMMING

motor of either the synchronous or induction type, supplemented by an adjustable speed d-c. machine of much smaller size and a motor-generator set of similar capacity. The frame of the a-c. motor is mounted on bearings so that the frame as well as the rotor may rotate.

SYNCHRONOUS MOTORS

At the Winter Convention two papers on the subject of synchronous motors were presented. The motor described by Mr. M. A. Hyde, Jr., was developed especially for low-speed applications requiring high starting and high pull-in torques with a low-current inrush. The damper construction instead of being of the usual squirrel-cage type is phase wound and in starting an external resistance is inserted in this circuit and the motor accelerates in a manner quite similar to that of the ordinary wound rotor induction motor.

The paper presented by Messrs. McLenegan and Ferriss discusses the design features of normal synchronous motors and shows how these features are varied to adapt synchronous motors to the requirements of various special applications. Among the various modifications discussed are the use of part-winding starting for applications where low-starting torques and low-starting inrush are desirable, also various methods of obtaining high-starting torque such as by means of over-sized motors, over-voltage, delta-Y starting,

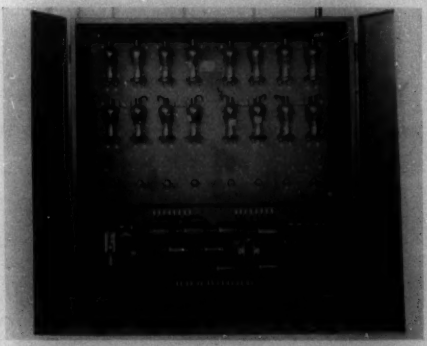

FIG. 14—ELECTRONIC TUBE CONTROL OF POLYCHROMATIC FLOOD-LIGHTING SYSTEM

tapped windings, phase-connected damper windings for both salient and non-salient pole motors, and a rotable stator scheme.

It is reported that the first application of a synchronous motor directly connected to a grain elevator leg was made during 1930. Ordinarily the starting torque required by these legs or bucket elevators is comparatively light but in case of emergency such as starting after a power failure, with the buckets loaded, a high-starting torque and a high pull-in torque are required.

Although several high-torque synchronous motors have been applied to primary or large gyratory crushers most of these have been of the standard mechanical construction and usually belted to the crusher pulley. A unique application has been made which utilizes a vertical motor of the umbrella type in which the revolving field poles are external to the stator which in turn is bolted rigidly to the frame of the crusher.

Another interesting and rather unusual application of a synchronous motor is for driving a hot copper rolling mill which requires continuous reversing service. The motor is guaranteed to reverse in five seconds and a special type of damper winding construction is used to increase the radiating surface and dissipate heat caused by the frequent starting and stopping.

For use in the Chilean Nitrate Industry a number of synchronous motors rated at 250 hp., 450 r. p. m., was built of the totally enclosed fan-cooled type. This construction is necessary to protect the motors against the saline solutions and vapors and the construction details are along very much the same lines as carried out on the smaller industrial motors.

When protected type motors are required either on account of injurious vapors or dust, it is sometimes undesirable or impossible to locate the control equipment in separate rooms and to take care of those cases

FIG. 15—MOTOR FOR LOWER ELEVATOR OF DUAL SYSTEM WITH COMBINATION MOTOR-GENERATOR SET AND CONTROL FOREGROUND

in which the control must be mounted in the same location as the motor, synchronous motor starters have been developed with the entire control immersed in a tank of oil.

ELECTRONIC TUBES

During the past year the electronic tube has become an accepted industrial device. Its original use was confined to the arts of communication and science and not until recently has any concerted effort been made to apply it to industrial purposes. Electronic tubes possess characteristics not available in older forms of electrical apparatus but offer many possibilities for industrial applications. These characteristics may be listed briefly as follows: speed of operation, small actuating energy requirement, amplification properties, accurate response, quietness of operation, and freedom from moving parts and contacts. In addition, the actuation of electronic tubes may be brought about by a large number of different physical effects including changes in resistance, inductance, capacitance, phase angle, frequency, temperature, sound, light, color, radio or carrier current.

There has developed a demand for electronic tube units which can be adapted to many applications for experimental purposes. Such units have been brought out by several manufacturers. The more common of these are the photoelectric units and electrostatically controlled arc discharge units. The tubes used in the latter are better known by the trade names of grid glow or thyratron.

In line with this increasing interest a paper entitled *Electron Tubes in Industry*, was presented by Mr. W. R. King at the Winter Convention. This paper gives a general discussion of the theory and characteristics of electron tubes without going into design details or calculations. Several of the more common control schemes involving tubes are explained for the purpose of showing how tube characteristics can be adapted to various applications.

To eliminate the human element in determination of smoke density a device utilizing a light source and photoelectric tube in connection with a recording instrument has been developed and gives a continuous accurate record of smoke density. The light source is mounted on one side of the stack and throws a beam of light through an aperture on the photoelectric tube mounted on the opposite side. The amount of light reaching the photoelectric tube is determined by the smoke density, and indicating or recording instruments may be installed at any convenient location.

One of the most interesting and largest electron tube applications is the control of lighting for stages and auditoriums. Installations of this type involve the use of between 300 and 600 electron tubes. Three installations of this type are in the Civic Opera House in Chicago, the Severance Memorial Hall in Cleveland, and a theatre in Los Angeles. The latest of these units, the one at Cleveland, has all of the control circuits operated from an organ type console. With this control it is possible to pre-set scenes, gradually fade from scene to scene with either manual control or automatically at a pre-determined rate, and vary the intensity of any light circuit in the hall individually or in combination with any other circuit or circuits. In the old types of stage lighting control the intensity was varied by means of rheostats. This new method uses three-legged reactors located conveniently for load distribution and the degree of saturation and consequent change in light intensity is varied by rectified direct current from tubes. Another application for the same type of equipment as used for theatre dimming is the control of building flood lights. On a large number of new buildings the lighting is so arranged that the shading and colors vary in some regular cycle.

Electron tubes are also being used for speed control

of d-c. motors in a number of various applications. At the present time for smaller motors, that is 3 hp. or below the control can be accomplished directly by control of armature voltage and current supplied from tubes, while for larger motors the field current only is controlled and supplied by tubes. One of the better known applications of this type is the maintaining of proper tension in the wire for a wire drawing machine and reel.

Photoelectric units have also been adapted to any number of production line applications where the objects are too light or fragile to operate ordinary control making or breaking devices by physical contact. On any application where an object can be made to intercept or otherwise vary a light beam this action can be used to actuate an operation. Some of the more common applications have been for counting, wrapping of packages such as foods, gum, etc., flag switches for reversing rolls as in steel mills, flashover protection of rotary converters, cutting of paper sheets to the proper length as required in connection with paper bag machines, paper break indicators in connection with paper machines, turning on and off lights in factories or offices to give proper illumination without wasting of power, and determining the transparency of paper.

Elevator Equipment

During the past year numerous improvements and refinements in elevator electrical equipment were made in keeping with the tendency toward higher speeds, automatic landing control, and quieter operation. The common trend toward combination units is also illustrated in elevator apparatus by building of motor-generator sets with exciter and control in one frame.

One of the completely new and interesting developments of the past year was the building of an elevator with two cars operating in one shaftway. Obviously the object of this arrangement is the saving of floor space in tall buildings where the space occupied by elevator shaftways is both valuable and large, inasmuch as the shaftway area must be subtracted from each floor. This elevator embodies all of the latest features in elevator design including automatic floor landing, door opening, and futuristically decorated cars. The cars use the floor bottom system of control and in addition a set of signals are displayed in each car indicating the relative position of both cars in the shaftway. The cars are prevented from approaching each other closer than two floors by an automatic block system of control which brings the car to a normal stop when this limiting distance is reached.

Conclusion

The Committee feels that there is a large field open for the electrical engineer in industry and that the Institute can be of material assistance to its members by bringing before them the important developments and trends in the various industries. In the preparation of this report we desire to acknowledge the assistance given by the various members of the committee and also by the Electric Machinery Manufacturing Co.

Instruments and Measurements

ANNUAL REPORT OF COMMITTEE ON INSTRUMENTS AND MEASUREMENTS*

THE Committee on Instruments and Measurements has been active during the past year on the following subjects:

1. Standard definitions for telemetering.
2. Standards for recording instruments.
3. Standards for indicating instruments.
4. Revision of Standards No. 14—Instrument Transformers.
5. Revision of Electrical Units.
6. Symposium on precision measurements.
7. Technique of temperature measurements.
8. Measurement of reactive power.
9. Method of measuring distortion factor.
10. Review of proposed papers.
11. Conclusion.

Standard Definitions for Telemetering

The subcommittee devoted to telemetering has been active for a number of years. Last year in this report there were published for comment standard definitions on this relatively new subject. It has been felt that, with the interest in the field of telemetering, it would be desirable to have some standard definitions so that the terms which are used would not be results from a hit and miss selection, as often occurs in newly developed fields. With comments received this year a set of standard definitions was approved by the membership of the Instruments and Measurements Committee, and is now ready for transmittal to the Standards Committee for adoption.

Standards for Recording Instruments

As a result of several years work, a subcommittee has completed a draft of proposed standards for recording instruments. These standards have been approved by the Instruments and Measurements Committee, and are now ready for submission to the Standards Committee.

The work of the subcommittee is under the chairmanship of Mr. Kinnard. A large amount of work has been involved in the development of these standards so as to cover this field of measuring instruments. The Committee has considered many new items which have shown that the Standards for Indicating Instruments should also be revised.

*COMMITTEE ON INSTRUMENTS AND MEASUREMENTS:

E. J. Rutan, Chairman,
H. S. Baker, M. Eppley, H. C. Koenig,
P. A. Borden, R. C. Fryer, W. B. Kouwenhoven,
H. B. Brooks, J. B. Gibbs, F. A. Laws,
O. J. Bushnell, W. N. Goodwin, Jr., E. S. Lee,
A. L. Cook, I. F. Kinnard, Paul MacGahan,
E. D. Doyle, O. A. Knopp, R. T. Pierce,
Melville Eastham, A. E. Knowlton, W. J. Shackelton.

Standards for Indicating Instruments

Since 1927, Instrument Standards No. 23 has been used by the industry. Since that time considerable progress has been made, and experience with the Standards has indicated that a revision would be desirable. A subcommittee was appointed at the beginning of this year to start the revision.

Revision of Standards No. 14—Instrument Transformers

A subcommittee has been active during the past year revising Standards No. 14 covering instrument transformers. This standard was approved in 1925. It was the feeling of the members of the Instruments and Measurements Committee that progress in the art warranted revision at this time. The committee is under the chairmanship of Mr. Gibbs. Several tentative drafts have been prepared and revised so that these standards will soon be in form to be submitted to the Committee membership for approval.

Revision of Electrical Units

The report of the Committee on Instruments and Measurements for the Institute year ending July 31, 1929, contained a brief account of the participation of this Committee in the events which led up to the first meeting of the (international) Advisory Committee on Electricity at Paris in 1928. At that meeting resolutions of far-reaching importance were adopted, to the effect that the absolute system of electrical units, derived from the c. g. s. system, may be substituted with advantage for the present international system of units which is based upon arbitrary legalized material standards, namely, the mercury ohm and the silver voltameter.

The second meeting of the Advisory Committee on Electricity was held in Paris in June 1930. The American representative on the Committee, Dr. G. K. Burgess, Director of the Bureau of Standards, was prevented from attending, and sent Dr. H. B. Brooks as his substitute.

Representatives were sent by the national standardizing laboratories of England, Germany, Japan, and the Soviet Republics; by the Laboratoire Central d'Electricite of Paris, and the International Bureau of Weights

and Measures at Sevres. Italy was represented by Professor L. Lombardi of the Royal School of Engineers at Rome. Other experts were present as invited guests. A large part of the sessions was taken up with the discussion of a new duty which the International Committee of Weights and Measures had recently laid upon the Advisory Committee on Electricity, namely, that of advising the International Committee on all questions relating to the methods of measurement and to the units and standards of light.

Concerning the primary standard of light, resolutions were adopted supporting the view that a black-body radiator should be adopted; requesting the national laboratories to examine the specifications for the Waidner-Burgess primary standard of light and to give their views regarding the practicability of its adoption; and urging the desirability of making additional determinations of the brightness of the black-body radiator, especially under the conditions prescribed by the Bureau of Standards' specifications, or at least under conditions comparable with them.

Concerning the unit of light and its maintenance, the Advisory Committee adopted a resolution to the effect that it is inexpedient to change the unit (*i. e.*, the international candle) which has been in use since 1909. Other resolutions adopted relate to the exchange and comparison of groups of lamps by the national standardizing laboratories, and to the adjustment of the values of the practical secondary standards, as may be necessary in the future as a result of reference to a primary standard.

Concerning the electrical units and standards, two resolutions were adopted, as follows:

1. With regard to the unit of resistance, the ohm, considering that methods of determining the absolute ohm are sufficiently advanced and that the agreement between the measurements of the coils (secondary standards) of the different laboratories remains within the limits of precision of the measurements, it is not necessary at present to undertake further comparisons of the resistance coils with mercury ohms.

2. As to the units of electromotive force, on the contrary, the international comparisons of standard cells show differences, exceeding the limits of possible precision, between the values of the electromotive force of the standards of different countries. The committee considers that it is absolutely necessary to make new determinations of the electromotive force of the international Weston cells in each national laboratory by means of the silver voltameter.

The conditions under which the silver voltameter should be used are specified sufficiently in the report of the international committee which met in Washington in 1910. The Advisory Committee recommends, however, that the national laboratories use the Smith or the Kohlrausch voltameter, avoiding organic material, which is detrimental to the electrolytic deposit.

The groups of Weston cells prepared in the several laboratories can be considered as sufficiently constant until the absolute unit of current shall be established.

It should be noted that these recommendations concerning standard cells and voltameters do not in any way modify the Advisory Committee's recommendation of 1928 looking to the ultimate legalization of the absolute ohm, volt, and ampere on a basis free from all arbitrary character. The recommendations merely recognize that the standard cell and the silver voltameter are useful tools, when properly used, and are essential to the maintenance and dissemination of the international electrical units under the existing limitations.

The Advisory Committee also made recommendations regarding the equipment of the International Bureau of Weights and Measures and plans for cooperation between that bureau and the national laboratories in work on electric and photometric standards. Since an international General Conference on Weights and Measures is to be held in 1933, the Advisory Committee decided that it should meet again before that time to study the comparisons of standards which shall have been made and to assign values in absolute units for the standards of resistance and of electromotive force.

Symposium of Precision Measurements

In view of the recent activity of the International Advisory Committee on Electricity, it was felt desirable to have some outstanding papers written concerning the fundamental electrical units. The subject is being treated in a symposium which is being presented at the 1931 Summer Convention and which includes four papers. These are:

1. *International Standard of Electromotive Force and Its Low-Temperature Coefficient Form*, by Marion Eppley, the Eppley Laboratory, Inc.

2. *The Unit of Electrical Resistance; Past History and Impending Change*, by H. B. Brooks, National Bureau of Standards.

3. *Design of Potentiometers*, by I. Melville Stein, Leeds and Northrup Company.

4. *Electrical Units and Their Application*, by L. T. Robinson, General Electric Company.

Technique of Temperature Measurements

In order to set up a standard code for temperature measurements, a subcommittee has been appointed. This committee has already analyzed all of the temperature requirements included in the various standards of the Institute, and is now summarizing these data preparatory to setting up the necessary measurement technique.

Measurement of Reactive Power

Considerable interest is being displayed in the matter of measurement of reactive power. A subcommittee has been considering this subject, and is cooperating with a committee appointed by the

Standards Committee under the chairmanship of Mr. A. E. Knowlton.

Method of Measuring Distortion Factor

In line with the recommendation of this Committee, made in last year's annual report, a subcommittee has been following the performance of Belfils Bridge which is being used by one of the manufacturing companies. The work has progressed to the point where a report has been prepared covering the performance of this apparatus. At the present time the report is in circulation among the members of the Instruments and Measurements Committee in order that their comments and recommendations may be obtained in regard to the suitability of this device for the measurement of distortion factor.

Papers

In addition to the four papers mentioned above in connection with the symposium of precision measurements, nine papers have been submitted to this Committee for review. Some of these have already been approved for publication and presentation and the remainder are in circulation and will be reported on shortly. These papers are listed below:

Measurements of Cable Insulation Characteristics

A High-Sensitive Power-Factor Bridge, by W. B. Kouwenhoven and A. Banos.

High-Voltage Bridge for Measurement of Cables with Grounded Sheaths, by C. F. Dawes and A. F. Daniel.

The Elimination of an Inherent Error in the Usual Form of Capacitance Bridge for Capacitance and Power-Factor Measurements by the Substitution Method, by R. P. Siskind.

Measurements of Magnetic Flux

Core Loss Measurements at High-Flux Densities, by B. M. Smith and C. Concordia.

This paper was presented at the Northeastern District Meeting, Rochester, N. Y., April 1931.

Miscellaneous Subjects

A Direct-Current Bushing Transformer, by A. S. Fitzgerald.

A New Overcurrent Relay with Straight Line Characteristics, by S. L. Goldsborough and R. M. Smith.

A Thermionic Type Automatic Synchronizer, by F. H. Gulliksen.

The Characteristics of the Oscillograph-Galvanometer, by V. S. Thomander.

The Amplifier-Oscillograph, by S. K. Waldorf.

Conclusion

Active interest has been shown by the members of the Committee on Instruments and Measurements through the year. The meetings held were well attended and subcommittee reports indicated considerable progress was being made in each of the assigned activities, and definite steps have been taken on several as indicated above. During the coming year it is expected to complete some of the other projects.

Applications to Iron and Steel Production

ANNUAL REPORT OF THE COMMITTEE ON APPLICATIONS TO IRON AND STEEL PRODUCTION*

THE functions of this committee have, in the past, been largely confined to (1) encouraging the presentation of papers before the Institute dealing with those phases of electrical engineering which are major factors in the utilization of electricity in the steel industry. (2) To preparing an annual report which briefly summarizes such phases of the application of electricity to the production of iron and steel as are considered new or of special interest to the membership.

During the past year, the committee's work has followed the previous precedent, in procuring papers. It also actively cooperated in arranging a joint session of the Institute with the Association of Iron and Steel Electrical Engineers at the meeting of the Middle Eastern District held in Pittsburgh on March 11th to 13th inclusive, 1931. The papers presented before this meeting which the members of this committee were active in procuring are as follows:

1. "Conversion and Distribution of General Purpose D-C. Power in Large Industrial Plants," by R. D. Abbiss, Carnegie Steel Co., and D. C. West, Westinghouse Elec. & Mfg. Co.

2. Symposium on Interconnection Between Utilities and Industries: Davison Coke and Iron Co. and Duquesne Light Co. Interconnection, by G. E. Dignan, Davison Coal and Iron Co. and R. L. Kirk, Duquesne Light Co.

3. "Interconnection of Power Supply Between Public Utilities and Large Industrial Users," by F. O. Schnure, Bethlehem Steel Co.

4. "Absorption of By-Product Power," by A. Hoeffle, Toledo Edison Co. and W. T. Woodmancy, Interlake Iron Corp.

5. "The Use of Electricity in Large Annealing Furnaces," by J. C. Woodson, Westinghouse Elec. & Mfg. Co.

The Committee wishes to report that this joint meeting of the Institute and the Association of Iron and Steel Electrical Engineers was a very successful part of the Middle Eastern District Meeting Program, and suggests that joint meetings with the Association of Iron and Steel Electrical Engineers be encouraged in the future.

*COMMITTEE ON APPLICATIONS TO IRON AND STEEL PRODUCTION:

A. C. Cummins, Chairman,
F. B. Crosby, A. G. Pierce, G. E. Stoltz,
M. M. Fowler, F. O. Schnure, Wilfred Sykes,
S. L. Henderson, W. B. Shirk, T. S. Towle,
A. M. MacCutcheon, H. A. Winne.

Electrical Developments in the Iron and Steel Industry During 1930

During the year 1930 there has been a general recession from the unusually high operating rates of the preceding year, and an accompanying reduction in expenditure for improvements and new plant facilities. However, an impressive amount of electrical equipment has been purchased and many interesting developments have taken place. Undoubtedly, the very successful electrification of rolling mills and their auxiliaries has been an important factor in the steel industry.

The iron and steel industry during 1930, purchased 163,490 total horsepower of main drive motors, rated 300 hp. or over, as compared to a total of approximately 350,000 hp. during 1929. The fact that the rate of increase in installed horsepower for main drives is greater than the rate of increase for ingot capacity, indicates the tendency to modernize old mills.

Direct Current Motors

Many important installations have been completed during 1930, with others rapidly nearing completion. From various viewpoints, a new 10,000-hp., 54-inch blooming mill in the Chicago District is memorable. It is the most powerful mill yet installed by a margin of 2,000 hp., an increase in power which will be useful in rolling thicker and heavier sections. This tends toward greater output of the whole plant, the blooming mill being the first of all the rolling operations.

Even more than for its size, this mill is unique in that the two main rolls, usually geared together, are driven individually, each by its own motor. This is a great improvement over the former method of a single motor coupled to a pinion stand. The ordinary construction of mill pinions and housings permits wear and misalinement from which develop accelerated wear, noise, vibration, and occasional breakage. Often the mill must continue in operation for several days after trouble has been developed before it can be conveniently shut down.

Each roll of the new 54-inch mill is driven by a double armature motor rated at 5,000 hp., 700 volts, direct current, at 40/80 r. p. m., both motors being under electrical control which keeps the speed of the two rolls precisely the same. The torque developed is 4,000,000 lb-ft., from standstill up to normal speed. The motors are of minimum diameter to avoid angularity of the

mill spindles between motor and rolls, an incidental advantage being smaller inertia.

Immediately following the 54-inch blooming mill just referred to is the 52-inch beam mill. The roughing mill is driven by a 7,000-hp. reversing motor, and a 2,000-hp. reversing motor for the edging stand. Likewise the intermediate mill will be equipped with reversing motors rated at 6,000 hp. and 2,000 hp.

There is now under construction by this same company, a 44-inch universal slabbing mill, the driving motors of which will have a continuous capacity of 12,500 hp., and a maximum emergency capacity of 35,000 hp. The upper and lower horizontal rolls are to be individually driven by two 5,000-hp., 40/80-r. p. m. reversing motors, constituting a twin motor drive of 10,000 hp., 4,000,000 lb-ft. maximum torque capacity, duplicate of the 54-inch blooming mill now in operation. The vertical edging rolls are to be driven by a third reversing motor, rated 2,500 hp., 79/225 r. p. m., 500,000 lb-ft. maximum torque capacity. Power for the three reversing motors will be furnished by a 10,500-kw. flywheel motor-generator set consisting of a 180,000-lb. flywheel, a 6,500-hp., 25-cycle, 6,600-volt, 370-r. p. m. induction motor, and three 3,500-kw., 700-volt generators connected in parallel. This installation will be of unusual interest to steel mill engineers because of the large size of the mill and the electrical equipment, and also because of the method of drive, utilizing three reversing motors with control to provide adjustment of relative speeds, thus permitting variations in drafting and the use of rolls of unequal diameter.

To secure the necessary refinement for the accurate automatic control of the screwdown mechanisms on a 32-inch three-high universal plate mill and on roughing and intermediate 52-inch universal structural mills, seven variable-voltage screwdown equipments have been installed. The variable-voltage control permits much more accurate settings than could be obtained with rheostatic control, either automatic or manually operated, and thus speeds up the operation of the entire mill. A further advantage is the elimination of the large capacity reversing and accelerating contacts and starting resistor, with accompanying lowered maintenance.

In addition to the 54-inch and 44-inch mills referred to above, this company is also completing a 96-inch continuous plate mill, a 10-inch alloy bar mill, a large open-hearth department, and a 20,000-kw. addition to the existing steam turbine power station.

The 10-inch alloy bar mill will be driven by nine direct current motors, totaling 7,627 hp. Some of the motors have a speed range of approximately 5 to 1, which is obtained partly by motor field adjustments and partly by armature voltage control through the use of auxiliary bucking generators, one for each of two motors which have this large speed range. The use of these bucking generators permits operating the three main 1,750-kw., 600-volt generators in parallel at constant bus voltage. The motors will be equipped throughout with speed regulators of the vibrating type, designed to hold the speed regulation within very close limits.

An 8,000-hp., 40/100-r. p. m. reversing motor is now being built to drive a 44-inch blooming mill at Gary. This motor will be capable of developing a maximum torque of 2,900,000 lb-ft. The mechanical parts of this motor, including the armature spider, will be of fabricated steel construction throughout. Several reversing motors with fabricated and electrically welded armature spiders have been in service for some time, demonstrating beyond doubt the reliability of this type of construction. Power for the 8,000-hp. motor will be supplied by a 375-r. p. m. motor-generator set, consisting of two 3,500-kw. generators, one 6,000-hp., 6,600-volt, 25-cycle induction motor, and one 200,000-hp-sec. flywheel.

A southern steel company has placed in operation at Alabama City, a new 40-inch blooming mill which replaces an engine-driven 36-inch mill. The 40-inch mill is driven by a 7,000-hp., 700-volt, 50/120-r. p. m., single-armature reversing motor supplied with power from a 6,000-kw. flywheel motor-generator set. This company has also installed a new 32-inch three-high universal plate mill driven by a 4,000-hp., 80/160-r. p. m., d-c. motor, similar to a reversing mill motor, with variable-voltage power supplied by a 3,200-kw. flywheel motor-generator. The major part of the mill output is light gage sheets. The type of drive used permits the operator conveniently to select low speeds for the roughing passes, and high speeds for the finishing passes, with very rapid acceleration to the desired rolling speeds. An important feature of this mill is the automatic screwdown. When the operator moves the pass master switch to each successive position, the desired screwdown setting for each pass is obtained by automatic control.

A 20-inch continuous hot strip mill in the Detroit District was put into operation in 1930. This mill has ten stands, each driven by an individual d-c motor. The drive for this mill has one very interesting feature. When rolling from slabs of such length that the piece will reach from stand 4 to stand 5, the section of the bus to which the first four motors and one 5,000-kw. generator set are connected, is segregated from the bus to which the remainder of the motors and the other generators are connected. This is necessary because the minimum speeds of the first four motors when operating at normal rated voltage are such that the metal would be delivered from stand 4 at a very much higher speed than it enters stand 5. Consequently, when the piece is continuous between stands 4 and 5, the speeds of the first four stands must be lowered by reducing the voltage of the generators on the section of bus to which the first four motors are connected. A similar arrangement was incorporated in the control of the first two motors on the 60-inch strip mill in a plant at Steubenville, Ohio.

Motor drive has for the first time been successfully applied on a large scale to the operation of a 900-ton ingot pressing application that was formerly monopolized almost entirely by steam or hydraulic operation. This press is in the new plant of a wrought iron manufacturer near the Pittsburgh District and compresses wrought iron sponge balls, about five feet in diameter, into rectangular ingots, measuring about 6 ft. by 18 inches square, preparatory to rolling in the blooming mill. On the final squeeze, it is necessary to exert a pressure of at least 1,000 pounds per square inch. Maintenance of factory production at full speed, requires operating the rams up to 75 feet per minute. Still the motors and press must be protected from the enormous stress which would result if the ram was brought up suddenly against a solidly compressed ingot. The solution of these and other problems involved a coordination of generator, exciter, and motor characteristics with manual and automatic control facilities, so that, as the pressure increases, the ram speed is slowed up towards the end of its stroke and the current will never exceed the allowable limit.

The main 900-ton ram is driven, through four racks and eight pinions, by a double-armature, 1,200-hp., d-c. reversing motor, having a normal full-load speed of about 125 r. p. m., and a maximum light-load speed of 275 r. p. m. The motor was built with two armatures in order to reduce the $W R^2$ and to halve the current to be carried by each commutator. The auxiliary 200-ton end rams are driven by a 325-hp. single-armature motor, having a nominal full-load speed of 250 r. p. m. and a maximum light-load speed of 550 r. p. m. The motors are of sturdy mechanical construction, with cast steel armature spiders, special armature coil bracing, and thrust bearings at the coupling end. Rear enclosing end bells are provided so that the motors may be ventilated. This is necessary as the motors carry heavy loads at very low speeds, and are therefore incapable of self-ventilation.

Variable-voltage d-c. power for the two press motors is furnished by a four-unit synchronous motor-generator set, consisting of a 1,000-kw. generator for the large motor, a 300-kw. generator for the small motor, a 1,500-hp., 80 per cent power factor, 6,600-volt, three-phase, 60-cycle, synchronous driving motor, and a 50-kw., 250-volt exciter.

In addition to the electrical features enumerated, the mechanical design of the press incorporates a number of features intended to provide safe and reliable operation. The faces of the main ram head and stationary side stop are not smooth but have corrugations vertically and horizontally across them, so that on the first impact, only about 10 per cent of the total face of the ram strikes the ingot and the ram has to move in about 1½ inches before the entire face strikes.

The electrically driven press has been in operation several months, and its success has demonstrated the practicability of electrical drive for such machines.

A mill in the Youngstown District has purchased the electrical equipment for a 10-inch bar mill having 12 tandem stands. Ten d-c. motors totaling 7,350 hp. with variable-voltage control from two 2,000-kw. motor-generator sets will be used with this mill. The mill will have two unique features, one being the method of speed control and the other is the use of vertical motors to drive the vertical roll main stands.

A speed regulator of the carbon pile type is used with each motor and with a master frequency generator to maintain a desired speed relation between stands. The customary bevel gear drive to the rolls has been eliminated by the use of vertical motors. The vertical motor is mounted above the mill on an overhung support. This support also carries the rolls and pinion housing. The rolls can be moved sideways or up and down with respect to the bar being rolled so that the vertical rolls can be lined up with the grooves of the horizontal rolls.

Synchronous Motors

Among the more important synchronous motors which have been purchased during the year may be mentioned two 4,500-hp., 156.5-r. p. m., 6,600-volt, 60-cycle units which will drive two rolling mills in the plant of a Pennsylvania manufacturer. This company also purchased one 5,000-hp., 360-r. p. m., 6,600-volt synchronous motor to drive a 24-inch billet mill and one 4,000-hp., 360-r. p. m., 6,600-volt motor to drive a 28-inch billet mill at the same plant early this year. This company put into operation a 3,000-hp., 100-r. p. m., 11,000-volt, three-phase, 60-cycle synchronous motor, driving a three-high billet mill. This motor is of interest not only because it is one of the few main roll motors operating at over 6,600 volts, but also because it is started directly from the 11,000-volt circuit.

A West Virginia manufacturer has purchased two synchronous motors, one 2,000-hp., 300-r. p. m. and one 1,000-hp., 360-r. p. m., which will drive the hot tin mills. This is believed to be the first installation of synchronous motors on mills of this character, previous practise having been to use induction motors with flywheels. Synchronous motors were chosen because of the necessity of maintaining a good power factor, and also because of the gain in efficiency. Not only is the synchronous motor itself more efficient than the corresponding induction motor, but the friction and windage losses of the usual flywheel and the power losses in the secondary resistor or liquid slip regulator are eliminated. It is estimated that the power per ton of tin plate rolled will be at least 5 to 10 per cent less than if an induction motor flywheel drive had been used.

Switchgear

All the modern improvements in switchgear equipment are rapidly being adopted by the iron and steel industry. The metal clad type of switchgear with its

live parts completely enclosed, excluding dust and dirt and at the same time protecting the operator from possible injury, is ideally suited to steel mill service.

Auxiliaries

Automatic screwdown equipment has been developed to the point where it will rapidly become more generally used. Two recent applications, one in a universal plate mill and the other in a structural mill have been mentioned in this article. The use of variable-voltage equipment for these screwdown drives has proved very desirable.

There is increasing industrial activity in the application of vacuum tubes and related devices. The crane operator on the soaking pit cranes for a 54-inch mill in the Chicago District will control the opening and closing of the soaking pit covers through the action of photoelectric cells. In another plant, a photoelectric cell acts as a "flag" switch to make the necessary set-up for registering the temperature of each billet as it approaches the rail mill. Undoubtedly, the field for such applications will rapidly increase.

The majority of the motor-driven heavy shears, such as bloom and slab shears, which are now in operation, are driven through clutches by induction motors equipped with flywheels. The mechanical clutches are a source of more or less trouble, and to eliminate these and also the losses in the continuously running motor and flywheel, several shears have recently been installed with d-c. motor drives, arranged to start and stop with each cut.

Two of these are in a new plant near Detroit. The larger of the two is an 800-ton slab shear, designed to cut a slab 8 inches thick by 25 inches wide. Another midwestern steel plant has recently placed in operation eight shears, cutting cold stock up to a maximum of ¼ inch thick by 42 inches wide. Some idea of the high rate of acceleration and retardation may be obtained from the fact that the shear makes a complete cycle in less than one second, and during this time the motor starts from rest, attains a speed of over 450 r. p. m., cuts the plate and stops.

A Pittsburgh tube mill has installed two scrap shears for crushing and shearing pipe up to 24 inches. They are of the new type with the shear motors starting and stopping for each cycle.

What is believed to be the first application of synchronous motors to flying shear drive is in connection with a 20-inch hot strip mill in the Detroit District. The shear is of the rotary flying type, and, to insure that the metal shall be cut into equal lengths, it is necessary that the speed of shear be synchronized with the delivery speed of the metal from the mill. To accomplish this, an a-c. generator is provided on each stand, from which the metal may be delivered. The shear is driven by a synchronous motor, the power for which may be obtained from any of the a-c. generators.

Three ore unloaders recently placed in operation at one of the Lake Erie Docks are interesting on account of their large size. The combined capacity of the three unloaders is 3,600 tons per hour, and the actual time for unloading a 10,000-ton boat is four or five hours. The bucket capacity for each unloader is 17 tons. Each unloader uses eight motors totaling 1,060 hp. The beam hoist motor is a 350-hp., 500-r. p. m., shunt-wound mill motor and the trolley travel motor is a 170-hp. motor, these two motors having variable voltage control. The bucket closing and opening motor is a two-speed wound-rotor mill type motor, and all other motors are a-c. motors. The motor-generator set for the variable-voltage control is mounted inside the beam and serves to help balance the stiff-leg weight.

As electrical improvements in the iron and steel industry are reviewed each year, the opportunities that exist for improvements in steel mill drives and auxiliary equipment become increasingly evident. These improvements will result from a close cooperation between the steel plant engineer, the mill builders, and the engineers of the electrical manufacturer.

Production and Application of Light

ANNUAL REPORT OF THE COMMITTEE ON PRODUCTION AND APPLICATION OF LIGHT*

Production of Light

Statistics on Incandescent Lamp Sales

THE sale of incandescent lamps held up remarkably well during the past year, large lamps showing a decrease of about 1 per cent as compared with 1929. The Central Station revenue derived from the two classes of service in which light is a large factor (domestic and commercial, small power and light) showed an increase of about 7.5 per cent as compared with the previous year, offsetting the reduction from other uses of electricity, and leaving a net increase of about 3 per cent.

The average lumens, watts, and efficiency of the large lamps sold last year all increased as compared with the year before. The average lumens went from 797 to 814; the average watts from 60.7 to 61.2 and the average lumens per watt 13.1 to 13.3.

Of the sixteen standard wattages from 10 to 1,000 inclusive, used in multiple service, three sizes 60, 100, and 200 watts, represent nearly half (46.6 per cent) of the total wattage demand.

The percentage of 110-volt and 115-volt lamps sold decreased slightly, while that of 120-volt gained as compared with the previous year. The percentage distribution for last year for 110-, 115-, and 120-volt lamps was 5.2 per cent, 48.9 per cent, and 41.3 per cent respectively. Lamps for 200-250-volt service decreased from 3.3 per cent to 2.6 per cent of the total quantity sold for multiple service.

The demand for street series lamps is concentrating on the 6.6 ampere rating. This now represents 71.2 per cent of the total; the next largest demand being 14.6 per cent which is for the 15- and 20-ampere compensator type lamps.

New Sources of Ultraviolet Radiation

A new type of lamp (called a glow lamp) has been developed which produces ultraviolet light by virtue of a glow discharge through mercury vapor between two hot cathodes of the oxide coated type. The two heater filaments for the cathodes are connected in series and their resistance produces a sufficient difference in potential to cause a discharge between the two cathodes, once they have become heated. The lamp is rated at 2 amperes and 18 volts. This lamp, designed for operation on alternating current requires a starting potential of some 35 volts, after which 18 volts is sufficient to maintain the discharge. One, two or three lamps may be operated on the ordinary 115-volt lighting circuit in connection with a suitable current-limiting resistance, reactance, or transformer. The glass bulb has been selected for its transmission characteristics so that the lamp will produce practically no radiation below 2,800 Angstrom units. In addition to producing the desirable radiations of ultraviolet light, it also produces blue and green light in the visible spectrum which may possibly be used to advantage in the future to supplement the light of Mazda lamps, to secure a nearer approach to a light subjectively white in color as well as to obtain the healthful ultraviolet radiation.

In last years report a new tungsten-mercury arc lamp was referred to. This lamp consumed about 315 watts. A lamp of the same general characteristics, but of about forty per cent of this wattage has recently been announced. The bulb is smaller, and is fitted with a metal cap which raises the operating temperature and pressure of mercury vapor in the bulb, and increases the efficiency of production of ultraviolet radiation. The ultraviolet output of the new lamp is approximately one-half of that of the older one. The transformer to be used with the new lamp weighs about 7½ pounds and is small enough so that it can easily be embodied in the design of fixtures, to permit a wider use of this type of lamp, especially a source for dual lighting service.

Still another type of lamp employing a tungsten filament, operated at a high temperature has been found to produce ultraviolet radiation in the biologically active range in sufficient quantity to be of value at least to poultry and animals where exposure times are not too short. Lamps for such service must, of course, be made with special bulbs which will transmit this radiation, and two sizes, 60 and 500 watts for operation on standard lighting circuits have been made available.

A powerful, long-burning type of carbon arc has been developed for the production of ultraviolet radiation which was described in an illumination item in the December issue of the A. I. E. E. Journal, page 1031.

Gaseous Conductor Sources of Light

An arc, in an atmosphere of krypton and sodium, has been described by Dr. M. Pirani.* This operates in a

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tube about one inch in diameter and 35 inches long which has to be maintained at a temperature of 350 deg. cent. (somewhat above the melting point of lead). A very high efficiency, about 70 per cent of the theoretical maximum, is obtained based on the input to the arc alone. With the supplementary heating required, the over-all efficiency would, of course, be reduced. Previous to this time sodium arcs with efficiencies of from 50 to 70 lumens per watt have been described. The light from such lamps, however, is nearly monochromatic and would, alone, be of limited utility for ordinary lighting service.

Dr. Pirani has also obtained great increases in brilliancy in mercury and in neon discharge tubes.†

The combination of hot cathode neon and mercury vapor lamps to produce light apparently white in color, at a high efficiency, (mentioned in our report for 1928) is again attracting interest, as is also the combination of the mercury arc with incandescent lamps.

Small Gaseous Conductor Lamps

These small negative glow lamps used for night lamps, indicative and current detectors, are now designed to operate on line voltages from 90 to 130, and to consume from 0.01 to 2 watts,. The former is merely an indicator, the latter gives a maximum normal candlepower of 0.2.

Photoflash Lamp

A lamp has been designed to produce a high intensity flash for use in photographic work, consisting essentially of crumpled aluminum foil in an atmosphere of oxygen, which is ignited by a small filament that can be operated on any voltage from 2 to 130. It is made in a bulb of the size and shape of the 100 watt lamp used for general lighting service.

The flash lasts approximately 0.02 second, the radiation is about such as would be obtained from a black body at a temperature of 4,000 deg. K. The flash is equivalent in candlepower to about 250 ordinary 500-watt lamps. It is noiseless and fumeless, the products of combustion being retained within the bulb. The lamp is finding wide use in the photographic field.

40-Watt, Gas-filled Lamp

The 40-watt lamp for ordinary lighting service is being changed from a vacuum to a gas-filled type, and, at the same time put in a slightly smaller bulb. The initial efficiency of the new lamp is slightly higher, and the light output is maintained better throughout life.

50-Watt Lamp

The 50-watt incandescent lamp, for general lighting service, has been removed from the regular schedules of the manufacturers of Mazda lamps. Its demand can apparently be shifted largely to the 60-watt size which is gaining steadily in popularity. The three sizes, 40, 50, and 60 represented unnecessarily close steps.

Zeitschrift fur Technesche Physik—Nov. 1930.
†*E. T. Z.*,—June 1930.

New Incandescent Lamps

Three new lamps for 110-, 115-, and 120-volt lighting service have recently appeared on the market. These are, a 5-watt lamp in a bulb ¾ inch in diameter, a 100-watt in a tubular bulb 34 inches long, and a 150-watt in a tubular bulb about 12 inches long.

Application of Light

Ultraviolet

The utility of ultraviolet radiation for purposes, other than merely the prevention of rickets, has been attracting wide attention and has been the subject of much experimental work. Its most promising physiological benefits seem to lie in the direction of prevention of colds and relief of anaemia. In the industrial field powerful carbon arcs are used for making accelerated tests (which must however be carefully evaluated) and for the treatment of food, tobacco, and other products. Small incandescent sources can be used in poultry houses with good effect.

The use of screens with arc sources to absorb the ultraviolet radiation shorter than that which it is desired to use, has grown during the past year, particularly in outfits intended for use in the home. A time limit switch is also incorporated with some outfits to reduce the probability of over-exposure. The development of very powerful arc sources with long-burning carbons, has extended the possible use of ultraviolet radiation in both industrial service, and in treating large groups in hospitals and sanatoriums.

Trends in Lighting Practise—1930

The interest of architects and decorators in the use of artificial light as a component part of their decorative scheme, is becoming more and more widespread. At first the new ideas were accepted in only the larger cities, now in most of the smaller cities and larger towns excellent examples of the new practise can be found.

Instead of trying to imitate flame sources, candles and oil lamps in fixtures intended for rooms of classical treatment, the skillful designer produces a luminaire which serves the modern light sources in an effective manner and then incorporates in the detail of decoration elements which are inherent to the decorative period under consideration.

The more commercial or stock fixtures which have appeared on the market during the last few months exhibit a tendency to new forms, characterized in general by simplicity of line and pleasing proportions.

If satisfactory illumination is to be obtained from side wall outlets, these must be fitted with some sort of device quite different from the ordinary candlestick bracket. Manufacturers are beginning to realize the possibility of so-called semi-indirect, side wall pockets or urns and a number of interesting varieties have been placed on the market during the period under consideration.

Only a few years ago it was the practise to finish the building and then choose the lighting fixtures. As a

result they often tended to appear as an incongruous after-thought, and not a component part of the structure. We are now seeing many instances of what has been termed "built-in" lighting, but these arrangements cannot be carried out unless suitable provision is made in the initial plans for the placement of lighting equipment.

There is a growing appreciation of the value of light to look at (as well as to see by) and in the more modern buildings we see interesting installations of luminous panels, niches, and touches of color which give no useful illumination but are pleasing to the eye.

Naval architects and ship owners realize that their vessels must be made more interesting from a decorative standpoint if they are to attract patronage under conditions of severe competition, and decorative lighting is receiving more attention than ever before in marine service.

There seems to be a trend in commercial lighting practise toward the greater use of indirect lighting equipment, both semi-indirect and totally indirect. Such forms of lighting which are desirable for general use in commercial interiors have been rather slow in being adopted probably because they require better maintenance than the enclosing globes.

Technical progress has been made in practically every field of lighting. In some of the newer ones, such as lighting for outdoor sports and for aviation, there has, in addition, been a very rapid growth. There have been no revolutionary changes, however, in equipment and methods generally employed.

Windowless Buildings

Perhaps the most outstanding development in connection with the use of daylight or artificial light for buildings that has taken place to date was started during the past year. The new factory of the Simonds Saw & Steel Company, Fitchburg, Mass., which is now nearing completion is built entirely without window openings. This pioneering project is receiving much publicity and the results will unquestionably be watched with interest and have a distinct bearing on the future building construction. In this building lighting units consisting of a combination of mercury vapor tubes and tungsten filament lamps will be used to secure a subjectively white color of light. Some of the tubes will be of ultraviolet transmitting glass to provide the desired amount of such radiation. Another notable example of this nature is the Parker Bridget Department Store in Washington, D. C. This store depends entirely on artificial illumination for its operation. It is felt that by eliminating windows lighting conditions are constant at all times. It is much easier to accurately control temperature and ventilation. Then, too, from a merchandising standpoint the larger percentage of wall area is available for display space.

With the record for continuity of service which has been attained by the central stations, and the development of effective means of lighting, ventilation and air conditioning, windows are no longer essential. There are so many advantages to be gained by their elimination in certain classes of use, that it appears as though this subject will receive increasing attention in the future.

Proper Operating Voltage

The N. E. L. A. Lamp Committee gives in its report this year, the results of further surveys of socket voltages, which show some improvement in the average value as compared with the sample cities studied the year before. The spread in voltage, however, shows no improvement. The results given in these surveys apply particularly to residential service. In large office buildings and industrial plants the average socket voltage is probably relatively lower than in residential service because of the greater voltage drop in interior wiring.

The N. E. L. A. Lamp Committee Report for 1928 contained a summary of data on operating voltages as reported in use for some 18,000 communities. This summary showed that 5.4 per cent of the population considered was in communities served at more than one standard voltage. Five years earlier the percentage had been 13.2. This trend toward the use of one standard operating voltage in each community aided in putting lamps of correct voltage in service, because, it is obviously difficult, if not impossible, to avoid mixing voltages in service where two or more standards are in use. The maintenance of but one standard service voltage throughout a community makes it much easier to be sure that lamps of only the correct voltage are used, and this is important from the standpoint of lighting service in general.

Minimum Wiring Specifications

In addition to the minimum specifications for the adequate wiring of lighting circuits in commercial and public structures, mentioned in last years report, specifications covering industrial and residential service will soon be made available as a result of further work by N. E. L. A. Committees. All of these specifications are in such simple form that they can be used with the greatest ease. They provide minimum standards to which all new buildings should conform in the interests of good lighting service. We again recommend that every electrical engineer who is brought into contact with the design or operation of lighting installations should be familiar with these specifications.

Stroboscopic Developments

A new type of stroboscope has been developed in which the discharge characteristics of a three-element grid glow tube are utilized in conjunction with a condenser to produce the brilliant flashes of light of exceedingly short duration and high frequency needed in such work. Another method, described in German technical literature produces flashes of the desired character by the combination of motion of three disks carrying different numbers of radial slits. A more complete description

of these devices has been submitted for publication as an Illumination Item.

Group Replacements

The replacement of incandescent lamps in street lighting service in complete groups rather than individually as failures occur, offers a possible means of securing a higher general level of illumination and reducing the number of outages at no increase in operating cost. It is being used, or tried out, in a number of localities. If the burning hours of all the lamps in a large group are identical, and if the cost of replacing lamps individually as they burn out is relatively high, it may be advantageous to replace the entire lot as soon as the burnouts begin to occur with some frequency, which will ordinarily be at the time the lamps have attained about 70 per cent of their average life. If this general replacement is made to coincide with one of the periodic cleanings of the lighting equipment the replacement cost per lamp is relatively small. This same practise might well be applied in other classes of service, where the cost of making individual replacements is relatively high, and where all the lamps in a large group burn the same length of time.

Fixed Focus Automobile Headlights

It has long been recognized that one of the greatest factors contributing toward glare from automobile headlights has been the fact that the lamp filaments were not properly focused in the reflectors. Although the system of approval of headlight equipment by the motor vehicle authorities of the various states after laboratory test has become quite general and all cars are equipped with head lamps capable of producing adequate road light with minimum glare, it has been impossible to keep these equipments in proper adjustment in the hands of the public. The motorists may learn to aim the headlight beams properly, but the more intricate operation of focusing the filament in the reflector has proved a stumbling block.

Because improvements in lamp manufacture now permit more accurate location of the filaments with respect to the lamp base, and because headlight reflector and lens combinations have been designed that are less sensitive to focal adjustment, it has become possible for the motor vehicle authorities to approve the use of so-called "fixed focus" headlamps from which the focusing mechanisms are entirely eliminated. The sockets in these headlamps are rigidly fastened in the reflectors and the filaments in the lamps of any reputable manufacturer in this country are accurately designed to fit them so that an acceptable beam can be secured by simply inserting the lamp in the socket.

Headlamps of this type are already being used by several of the motor car manufacturers and improvements in the general headlight situation are to be expected as their use becomes more widespread and cars with the old types of equipment are gradually replaced on the highways.

General

Present Status of Candlepower Standards

While the needs of practical photometry have been met reasonably well for many years by the expedient of establishing units of candlepower maintained by means of electric incandescent lamps, this procedure does not give a permanent solution for the problem of photometric standards. There remain unsettled three major difficulties: 1. Several countries, particularly Germany and Austria, still use the Hefner unit, which is 0.9 of the unit recognized by the International Commission on Illumination; 2. no reproducible primary standard has been accepted as representing the international unit which was established for carbon-filament lamps; 3. no specific method has been agreed upon for passing from the carbon-filament lamps to those giving light of other colors.

These difficulties have resulted in discrepancies between measurements made in different countries. The differences are large enough to be very serious in such precise measurements as are made in rating and testing incandescent lamps. Consequently efforts have been made for several years to find a basis for a comprehensive international agreement on this subject. These efforts have been furthered by discussion at several sessions of the International Commission on Illumination. In order to give a more definite legal status to the negotiations the International Committee on Weights and Measures decided in 1929 to take up the problem of photometric units and standards, collaborating with the Commission on Illumination. Both of these organizations meet in 1931, and it is hoped that some definite progress can be made toward the solution of the problem.

As a basis for action, an international Advisory Committee on Electricity, meeting in June, 1930, has prepared recommendations which may be summarized briefly as follows:

1. As a *primary standard of light* a black-body radiator is definitely recommended; other laboratories are asked to consider the specific form of standard which has been developed by the Bureau of Standards, and to make determinations on that form or on others which will be comparable with it.

2. As a *unit* for general use the present international candle is to be retained.

3. Present discrepancies between basic units at carbon-filament color as maintained in the different national laboratories are to be reconciled by comparisons now in progress, and thereafter periodic comparisons and necessary adjustments are to be made under the auspices of the International Committee on Weights and Measures.

4. Through comparisons of colored filters now under way between the national laboratories it is hoped that agreement can be reached on a standard method for measuring lights of various colors. This method can then be used in setting up practical standards for lamps of various types, all based upon the primary standard and all consistent with each other.

Architects and Lighting

During the past year the Illuminating Engineering Society has given great attention to securing better

cooperation between the architects and illuminating engineers. As one approach to this problem, three very well attended schools on architectural problems have been held, one at Columbia University, one at Chicago, and one at the Massachusetts Institute of Technology. Such schools for illuminating engineers serve to acquaint them with architects' viewpoints and nomenclature, thus helping to bridge the gap between the two professions. On the part of practising architects greater attention than ever before has been given to coordinating lighting with building design.

Important steps have been taken in fostering better lighting in the homes and schools of the United States. In this manner the best principles of lighting have been made available to school boards and home owners. This work is spreading rapidly.

A code of principles of Street Lighting has been prepared by the Street Lighting Committee of the Illuminating Engineering Society, which is likely to take a very important part in guiding the practise in this field. For the first time experts and engineers representing diverse interests and viewpoints have been able to agree upon a statement of some of the fundamental factors involved.

The Lamp Committee of the National Electric Light Association presents each year to that association a report in which the statistics relating to incandescent lamp production are analyzed in detail, and in which important developments in the production and application of light are reviewed. Those who wish more detailed statistics, as well as those who are concerned with the commercial and engineering problems of lighting, will find valuable the reports of various committees of the National Electric Light Association and the Illuminating Engineering Society.

The Committee wishes to record its appreciation for the assistance rendered in the preparation of this report by Dr. E. C. Crittenden (who contributed the section on the Present Status of Candlepower Standards), Mr. A. L. Powell, and Mr. A. B. Oday.

Applications to Mining Work

ANNUAL REPORT OF COMMITTEE ON APPLICATIONS TO MINING WORK*

THERE has been a minimum of new installations made this year owing to the general depression.

Hoists. Probably fewer hoists have been installed than in many past years. It is interesting to note that two manufacturing companies alone report that combined they have sold to date nearly 800 induction motor hoists from 200 to 1,800 hp. in size, and over 100 variable control d-c. hoists from 200 to 5,000 hp., the latter two motors in series.

Cleaning Plants. There is a continued trend toward larger and more complete preparation plants especially at mines using mechanical loading instead of hand loading. One plant, Hazle Brook Coal Co., has installed two 200-hp. Westinghouse synchronous motor drives.

Shovels. Electrification of 4- to 10-yard shovels has continued in the metal mines.

Mining Machines. The manufacturers of this specialized electrically driven equipment have been very active in producing new types of mobile high-powered machines. These machines now undercut from 600 to 1,200 tons per day in contrast with older types which did well to undercut 200 tons per day. See Fig. 1.

Loading Machines. Rapid increase of the amount of coal mechanically loaded indicates that these labor saving devices are permanently established in the industry. Various makes have sustained records of 350 to 500 tons loaded per 8 hours. Probably there are 500 such machines now in operation.

Welding. In addition to miscellaneous repair work by electric arc welding several companies have installed full automatic welding heads to be used for filling up the worn tread of locomotive tires and wheels. This has been quite successful and undoubtedly will be very generally used.

FIG. 1—JEFFREY 29L TRACK-MOUNTED CUTTER

Safety Work. The Bureau of Mines has continued to test and approve many new devices for mining work.

NOTE: Many references to miscellaneous improvements and applications are given in the *Coal Age*, Vol. 36, No. 2, Feb. 1931, p. 76.

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Applications to Marine Work

ANNUAL REPORT OF COMMITTEE ON MARINE WORK*

THE major items of activity of the committee for the current term have been:

a. Reprinting Standards No. 45—Recommended Practise for Electrical Installations on Shipboard.

b. Promoting licensing of the electrical operating personnel on shipboard.

c. Keeping in touch with electric propulsion of ships and the electrification of auxiliaries on shipboard.

Standards No. 45

During the last term of this committee these standards were completely revised to incorporate developments and expansion in the marine practise since the previous issue of June 1927. They were carefully edited and reprinted in October 1930 and are being rapidly sold to all departments of the marine industry interested in electrical work. These standards are recognized and accepted by the various marine classification and insurance societies, naval architects, marine engineers, shipbuilders, and ship owners and are being incorporated in many of the specifications regulating the construction and repair of ships. The increasing use of them testifies to the need of such rules in order to standardize the electrical installations on shipboard and to stimulate the use and proper care of electrical machinery in the marine field.

They are referred to in the various rules of classification societies not as a requirement but as representing good practise. This regard for these rules is justly merited due to the many years of hard work by experienced representatives of the diversified interests composing the marine field.

The fire alarm rules in the present Steamboat Inspection Service are consistent with the Standards No. 45 and were referred to this committee during their preparation.

Fig. 1—View in Lower Engine Room, *S. S. Morro Castle*

Propulsion motor in background

Operating Personnel

Our efforts were continued with the Steamboat Inspection Service to obtain classification and rating for electrical operating engineers on shipboard.

Fig. 2—View in Upper Engine Room, *S. S. Morro Castle*

Propulsion control at left and generators at right

A review of the work of the subcommittee in charge of this item carries one back to the year 1922 when overtures were made to the Steamboat Inspection Service to require the operating personnel on vessels with electric plants to qualify and obtain electrical licenses.

The committee's efforts to date have been rewarded by a slight raising in the standard of the electrical

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H. M. Southgate,
W. E. Thau,
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A. E. Waller,
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R. L. Witham,
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questions in the examination for license for steam and combustion engineers.

The Board of Supervising Inspectors has been very courteous and granted a number of hearings. The necessity for the requested action, is recognized by a few of the supervising inspectors and it is hoped that there will soon be a sufficient number to put the movement into effect.

The cause for this movement was the improper maintenance of electrical equipment on shipboard and is today perhaps more prominent than when the movement was started owing to the increase in the use of electrical apparatus and auxiliaries, with the exception of vessels equipped with electric propulsion and all of these are not immune.

On electrically propelled vessels the standard of the electrical force is somewhat higher than on other vessels. Consequently, the electrical apparatus and auxiliaries receive the benefit of more expert attention.

The committee has been in touch with the President of the American Steamship Owners Association soliciting its good offices. Our committee was cordially received and has been requested to submit its proposal relative to the absence of knowledge and training on the part of the operating personnel. This proposal is almost complete and it is hoped it will be submitted at an early date.

The subcommittee is keeping in close touch with this situation and is optimistic in feeling that favorable action will be taken by the Steamboat Inspection Service before long and their regulations modified accordingly.

Electric Propulsion and Electric Auxiliaries

The year 1930 takes its place in marine history of the United States with a record of activity, progress, and accomplishment in shipbuilding and marine engineering, which has not been approached since the busy days of the World War. This is, of course, due largely to the stimulation resulting from the Jones-White Merchant Marine act of 1928, which has made available to American ship operators, large mail contracts and loans at low interest rates for construction of new vessels. Thus, our merchant marine is to receive a much needed strengthening by the addition of a fleet of fine ships now under construction or in process of design.

In the design of these last words in naval architecture, electricity has taken an outstanding place. Some will be propelled by means of electricity. All will have electrically driven auxiliaries which are so necessary to the operation of the ship. Electrical appliances will add to the comfort and convenience of the passengers.

In order to illustrate the progress of electric propulsion especially during the past year the following data covering vessels completed or contracted for to January 1, 1931, are listed below.

	Hp.	No. vessels
Total turbine electric in U. S. A.	867,600	62
Total turbine electric outside U. S. A.	127,900	9
Total	995,500	71
Commissioned or under construction during 1930 in U. S. A.	196,900	20
Total diesel electric in U. S. A.	88,280	121
Total diesel electric outside U. S. A.	16,700	8
Total	104,980	129
Commissioned or under construction during 1930 in U. S. A.	15,195	25

It may be interesting to know the individual vessels and their horsepowers involved in the above figures.

Name		Horsepower
Turbine Electric Drive—Ships Commissioned During 1930 in U. S. A.		
Santa Clara		12,600
Morro Castle		16,000
Oriente		16,000
City of Flint (Great Lakes Car Ferry)		7,200
Corsair		6,000
4—Coast Guard Cutters		12,880
2—River towboats		4,000
Total		74,680
Turbine Electric Drive Equipments—Under Construction During 1930		
President Hoover		26,500
President Coolidge		26,500
United Fruit Co.—6 ships 11,000 hp. each		66,000
One Coast Guard Cutter		3,220
Total		122,220
Diesel Electric Drive—Installed During 1930		
Frying Pan	Lightship	350
Fenwick Island	Lightship	350
Nantucket	Lightship	350
Tidewater	Tanker	1,000
Ward Island	Ferry	400
Tenkenas	Ferry	400
Veedol No. 2	Tanker	1,000
L. T. C. No. 1	Tanker	500
L. T. C. No. 2	Tanker	500
L. T. C. No. 3	Tanker	500
Liston	Survey Boat	350
Scott	Towboat	150
Ft. Armstrong	Towboat	150
Cleveland	Tug	800
Rochester	Tug	800
Scranton	Tug	800
Oleon	Tug	800
Venus	Tug	515
Luna	Tug	515
Prescottont	Tug	800
One tug *Vandyke No. 4.*		425
Total		11,455
Diesel Electric Drive—Under Construction		
One yacht		660
One tanker		200
One fireboat		2,130
One ferryboat		750
Total		3,740

Prior to the commissioning of the *S. S. California* in 1928 the total turbine-electric horsepower installed on merchant ships was but 38,800. Out of a total of 356,200 horsepower completed and in course of construction as of the end of 1930, 317,400 horsepower, or

89 per cent, was undertaken during the past three years.

Slightly apart from the marine field, but with equal interest to it, was the installation of a central station in the *Jacona*, which is to be used as a mobile and subsidiary power plant along the shores of the New England Coast. Two turbine generators were installed, each rated 10,000 kilowatts for delivering power ashore at 6,600 volts or 11,400 volts three-phase 60 cycles.

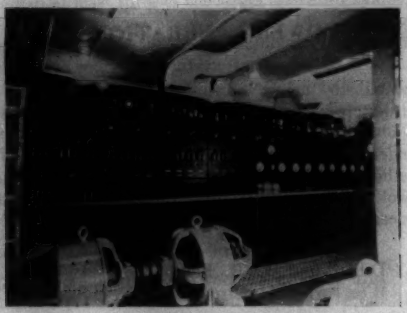

FIG. 3—AUXILIARY D-C. SWITCHBOARD, *S. S. Morro Castle*

During 1930, a 96-in. (wheel diameter) gyroscopic stabilizer complete with electrical equipment, was constructed. This unit will be installed in a large yacht. A second unit with 11-ft. diameter wheel, complete with electrical driving motors, control and turbine generator set for power supply, is nearing completion for installation on one of the largest yachts ever built. The casing of this stabilizer will be of welded construction.

During the year 1930 great strides were made in shipboard installations of modern watertight door control systems. This system provides that in the event of collision electric operation of the watertight bulkhead doors is instantly available. The system provides remote control of the watertight doors from the wheel house as well as at the door itself.

It is the intention of this committee to keep Standards No. 45 up to date and assist in any practicable way the various classification societies and other bodies or interests in the marine field in the application of electricity to marine use.

We further are ready to cooperate with the American Marine Standards Committee in establishing electrical marine standards such as watertight receptacles, etc.

Power Generation

ANNUAL REPORT OF COMMITTEE ON POWER GENERATION*

TWO meetings of the entire committee were held during the year, one at the Philadelphia District Meeting on October 14, 1930, and the second at the Winter Convention in New York on January 28, 1931. In addition to the regular survey of immediate developments and problems in the scope of the committee, a continuing organization or method was adopted through which news items on the subject of power generation will be reported for publication in ELECTRICAL ENGINEERING. Each member of the committee was asked to appoint some one of his business associates as a permanent news correspondent to represent his particular affiliation irrespective of membership in the future on the Power Generation Committee.

The subject of interconnection continued to occupy the major attention of the committee, and especially of the Joint Interconnection Subcommittee on which Messrs. F. C. Hanker, F. H. Hollister, and A. E. Silver represented the Power Generation Committee. The formation of this subcommittee composed of members from the Power Generation, Power Transmission and Distribution and Protective Devices Committees, was predicted in last year's report, and the subcommittee has functioned throughout the year under Mr. Hanker's chairmanship not only to the fullest extent, but has also promoted a close working arrangement among the three main committees in dealing with a subject that has many common elements.

The Joint Interconnection Subcommittee has directed the preparation of a second report on "Grounding," which was presented at the Pittsburgh meeting in March 1931 under the title *Present Day Practise in Grounding of Transmission Systems*, and while of technical import to this committee, is also of interest because the original report on *Grounding* was prepared in 1923 by Mr. E. C. Stone now of the Power Generation Committee.

The Interconnection subcommittee has also sponsored a session in this summer's convention, consisting of four papers that treat the subject of interconnection primarily from the viewpoint of geographical, as contrasted to urban territory, interconnection. The introductory paper, prepared by Mr. Alex. E. Bauhan, is a comprehensive summary of the various services rendered by interconnection, and an exposition of the methods of evaluating the economies to be secured. Two papers that illustrate the plans and operating procedures adopted in different regions, are as follows:

Interconnection in New England, by E. W. Dillard and W. R. Bell; *The Pennsylvania-Ohio-West Virginia Interconnection*, by Howard S. Fitch.

The fourth paper, by G. M. Keenan, is on *Load and Frequency Control on Interconnected Systems* and summarizes the methods in use and the experience on the subject that has accumulated in the past two to three years on practically all the major system interconnections in this country.

The committee reviewed during the year and recommended as of great interest on the subject of interconnection other papers as follows:

Governor Performance During System Disturbances, by R. C. Buell, R. J. Caughey, E. M. Hunter, and V. M. Marquis.

Reestablishing Excitation of a Loaded Alternator in Parallel with Others, by D. D. Higgins and E. Wild.

Other papers describing the design of modern power plants that have been reviewed by the committee include the following:

The Ohio Falls Hydroelectric Station at Louisville, Kentucky, by R. M. Stanley and E. D. Wood.

Modern Steam Stations of Duke Power Company, by Marshall E. Lake.

Steam Power Development of the Pacific Gas and Electric Company, by Richard C. Powell.

Two papers with an introductory summary have been initiated and are now in preparation on the subject of steam and electric drives. These papers are being written in collaboration for the purpose of uniform presentation, and are scheduled for one of the fall meetings this year.

Another activity initiated that will result in a symposium during the 1932 Winter Convention, is suggested by the lack of information reported to the committee on the subject of system operation from the viewpoint of economy and reliability in carrying load schedules. There is considerable literature relating to load division among boilers and generating units

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J. B. Crane,	F. H. Hollister,	A. E. Silver,
H. W. Eales,	A. H. Hull,	W. F. Sims,
N. E. Funk,	G. A. Jessop,	A. R. Smith,
D. L. Galusha,	H. W. Leitch,	E. C. Stone,
R. B. Gerhardt,	E. B. Meyer,	R. W. Stovel.
	E. L. Moreland,	

in single stations, but new problems in load allocation have resulted from the extensive interconnection of systems previously operating as separate units. It is planned to secure a series of papers describing the practise of at least three of the larger operating systems on which steam generation is exclusively employed, and to reserve the subject of combined steam and hydroelectric sources for later discussion.

The Progress Report which follows, covers the developments of the past two years. Together with a bibliography of the more salient literature on power generation.

Recent Developments and Present Status of Power Generation

Volume and Distribution of Generation

The combination of a two-year drought and the business depression had a marked effect upon the distribution of the total electric generation in the United States between fuel burning and hydroelectric plants. From 1921 and 1928 the average yearly increase in total generation was quite uniform at 11.5 per cent, in fuel generation at 10.9 per cent, and in hydroelectric generation at 12.7 per cent. Applying these average rates to the figures for 1928 there is a calculated deficit at the end of 1930 of 12.1 per cent in total generation, 4.0 per cent in fuel generation, and 32.5 per cent in hydroelectric generation. These figures show that the loss in hydroelectric generation caused by the drought allowed fuel generation almost to hold its normal increase notwithstanding a decrease of 1.5 per cent in total generation in 1930. The total generation in 1930 was 96 billions, of which 34.6 per cent was generated in hydroelectric plants in contrast to 40.4 per cent in 1928.

Generating Plant Building Programs

The added steam generating capacity in the United States in 1929 was secured by about 57 per cent in new plant construction and 43 per cent in additions to existing plants. The total added capacity was nearly 2,250,000 kw. It is interesting to note that in 1930, in spite of the fact that the total electric production for the year was about 1.5 per cent below that of 1929, there was nearly as much steam generating plant capacity added as in 1929, a total of slightly over 2,000,000 kw. This was divided 47 per cent in new plants and 53 per cent in additions to existing plants. Apparently the depression of the past year is to be reflected in the amount of capacity contemplated for 1931 additions, which is about 1,250,000 kw. These additions are mostly in existing plants where the added capacity is 75 per cent of the total, a condition approaching that of 1928, when practically all of the new steam capacity was in additions to existing plants.

Compared to 1928, the number of new hydroelectric plants and the capacity installed in 1929, was strikingly small; the new installations in 1930 were over three times greater than in 1929, but they still were appreciably less than in 1928. The plants now under construction that will be completed in 1931 will total about 50 per cent of the additions to capacity in 1928, while present indications are that the new capacity developed in 1932 will be only a fraction of the 1931 installations. Contrasted to the schedule of immediate construction are the probabilities within the next few years of the super-capacity plants that are being considered on the Columbia, Colorado, and St. Lawrence rivers.

Major Influences in Current Design of Steam-Electric Plants

The fundamental factors influencing the design of modern steam-electric generating plants are about the same as those which dictated design in the past. They are only modified by new and better apparatus now available, such as improved and alloy steels which make possible the use of higher pressures and temperatures, improved fuel burning equipment and furnaces which permit of much higher boiler ratings and greater efficiences, together with numerous other improvements in auxiliary apparatus.

For a number of years the tendency of steam plant investment costs was upward and these increased costs were justified by the considerable improvement in economy. The point has now been reached where improved efficiencies are becoming increasingly difficult to secure, and any increase in capital cost is difficult to justify. It would seem, therefore, that the effort to lower production costs must lie in reductions in capital investment through simplified design, raising the output of the equipment, and increasing the capacity for a given unit of space.

Probably the most attractive feature in a program of simplification is the possibility of reducing the number of boiler units for a given turbo generator output. Reports published within the last year indicate that the modern boiler has a reliability factor practically equal to that of the turbo generator. It would, therefore, seem that spare boiler capacity should be considerably reduced over past practise up to the point where boiler and turbine capacity would be equal. In other words, the boiler and turbine might be considered as one complete unit. This would be particularly practical where there are several units in the same station, in which case a certain degree of flexibility could be secured where a boiler and turbine forming separate units might be out of service, in the one case for boiler inspection or repairs and in the other case for turbine inspection or repairs.

The greater cleanliness in the operation of fuel preparation and feeding apparatus will now permit the installation of turbines, boilers, and fuel equipment in single buildings without the use of the dividing walls which have up to this time been considered necessary. There has been a number of instances where plants have been constructed without these walls and are

giving very satisfactory operating results. The omission of dividing walls not only saves the cost of the wall but reduces the amount of building steel and permits of a more compact arrangement of apparatus, thus bringing about a natural reduction in the cubic contents of the building. In certain cases a reduction in operating labor has also been secured.

Outdoor installations of boilers, turbines, and electrical equipment are advocated by some engineers and many attractive studies have been brought forth. To date, however, no large outdoor installations have been projected. While such installations are not in entire favor with operating engineers the reduced investment has made the designs of interest.

In practically all of the older designs there was a great deal of duplication in the piping layouts. Numerous cross connections, loops and sectionalizing valves were used, partly with the idea of protecting against failure of any part of the piping system and partly due to the desire to protect against failure of apparatus used in the feed-water heating cycle. Experience with operation of piping, valves, and equipment has shown that their factor of reliability is, in general, as great as that of the turbines and boilers. The opinion has

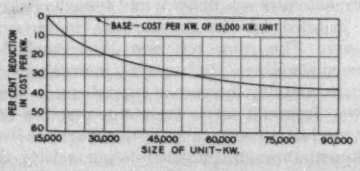

FIG. 1—PER CENT REDUCTION IN UNIT COST OF SINGLE SHAFT TURBO-GENERATOR UNITS DESIGNED FOR 450 LB. 775 DEG. FAHR. STEAM

frequently been expressed that provisions made for cross-connecting and sectionalizing have never been used even though they have been in the plant for a considerable number of years. Simplification of piping design and reduction in number of valves, joints, etc., would reduce both the capital expenditure and the operating cost.

Considerable thought has been given to reducing the number of duplications of auxiliary equipment, such as condensate, air and circulating pumps for turbo generator units. In designs where several spare boilers were provided it was the practise to install single auxiliaries such as stoker drives, forced and induced draft fans, whereas on the turbo generator units it was customary to duplicate the auxiliary equipment. With the present consideration being given to reduction and possible elimination of spare boilers, the question of duplication of auxiliaries should be carefully considered. The usual argument that it is good insurance to protect the large unit by the installation of duplicate and comparatively cheap auxiliaries, carries some weight. Against this, however, must be balanced the lower capital and operating costs by minimizing the number of pieces of apparatus and simplifying the piping design.

The use of larger units, both boilers and turbines, has resulted in a lower unit cost of equipment and in a marked reduction in the cost of the building per kilowatt of capacity. There is a number of installations either already made or pending, where the capacity of the new turbo-generator unit is from two to three times that of the unit for which the building was originally planned. It is evident, therefore, that the

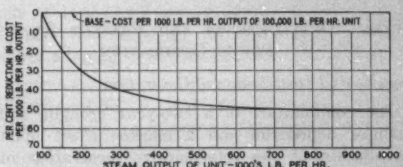

FIG. 2—PER CENT REDUCTION IN COST OF BOILER UNITS DESIGNED FOR 450 LB. 775 DEG. FAHR. STEAM

Prices used in plotting the curve include cost of boiler, superheater, soot blowers, air heater economizer, and pulverized fuel equipment

cost of this portion of the building per kilowatt would be reduced to one-half or one-third of the original cost. A few years ago the cost of buildings per kilowatt of capacity was roughly $30. It is, therefore, evident that the possible savings in building alone due to use of larger equipment results in a material reduction in cost per kilowatt. This would have a particular application where equipment is to be installed in a vacant space in an existing building or where it is desired to increase the capacity by replacing equipment in an old plant which is strategically located in the distribution system.

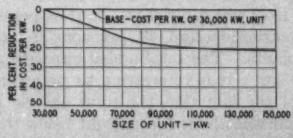

FIG. 3—PER CENT REDUCTION IN COST OF SINGLE SHAFT TURBO-GENERATOR UNITS DESIGNED FOR 1,000 LB. 775 DEG. FAHR. STEAM REHEATED TO 775 DEG. FAHR.

The reduction in floor area has assumed importance not only from the standpoint of building and land value but from the resulting reduction in cost of much of the piping and auxiliary equipment. In order to reduce the floor area some of the modern designs resorted to the vertical compounding of units as typified by the Jersey Central Power and Light Company and the Pacific Gas and Electric Company where a high pressure turbine and generator are mounted on top of a low-pressure generator. By such means and by the

increase in the maximum size of turbines from 50,000 kw. in 1920 to 200,000 kw. at present, the floor area has been reduced from an average of 42 sq. ft. per installed kilowatt to less than half that area.

Typical of this trend are the Ford Company in which a 110,000-kw. unit is to be installed where one 12,500-kw. unit is being removed; the Hell Gate Station of The United Electric Light and Power Company where two 160,000-kw. units have been installed in the space designed for two 35,000-kw. units and the Hudson Avenue Station of The Brooklyn Edison Company, Inc., where two 160,000-kw. units have been purchased for the space designed for two 50,000-kw. units.

Along with the increase in size of turbines the weight per kilowatt including the generator has been reduced in the past ten years from about 28 lb. to 15 lb.

The curves in Figs. 1, 2, and 3 will give an indication of the trend toward lower costs with increased size of turbo generators and boilers per unit of capacity. Figs. 1 and 2 represent respectively cost trends for turbo generator and boiler units designed for 450 lb. pressure and 775 deg. fahr. total temperature. Fig. 3 is representative of a compound single-shaft turbo generator where the initial steam condition would be 1,200 kw. and 775 deg. fahr. total temperature, with steam bled at 400 lb. and reheated to the initial temperature.

Along a line totally different from the selection and arrangement of equipment, and also for the purpose of reducing the cost of power generation, has been the cooperative interconnections adopted in the last few years between steam-electric stations and industrial plants. The latter in some cases require large quantities of steam under conditions that may or may not be suitable for the supply of power necessities; in other cases the industrial plants may have the disposal of byproduct fuel either solid or gaseous. It has been found advantageous to both parties in a variety of industries to arrange both electric and steam interconnections whereby power and steam are generated in the most economical fashion, and the fullest benefit derived from diversity in power, steam, and byproduct conditions. In many instances the electric plant supplies both steam and electricity, requiring certain modifications in the standard feed water system. Recent literature has described such arrangements at Deepwater, New Jersey, Rochester, New York, Toledo, Ohio, Baton Rouge, Louisiana, Mobile, Alabama, and Cedar Rapids, Iowa.

Factors at Present Determining Maximum Size of Boilers and Turbines

While large unit size turbo generators reduce the cost per installed kilowatt they sometimes represent a greater capital charge for reserve capacity. A check of available published information regarding peak loads and installed capacity in fourteen large central station systems indicates the following reserve capacity in per cent of the total installed:

Four systems were between 30 and 36 per cent.
Seven systems were between 20 and 30 per cent.
One system was about 17 per cent.
Two were less than 10 per cent.

The same published information indicates that the two systems having the smallest reserve capacity have a substantial percentage of purchased power, so that it is very probable that actual reserve capacity would be materially increased by available spare capacity through interconnection. In one of these systems, where the per cent of reserve capacity is the greatest, it is known that the generator capacity reported on was not all available at the time the tabulation was made, since the boiler capacity in one of the principal plants limited its capacity to a point considerably below the generator name plate ratings. The selection of the very large units in some of the recent developments may have been due to a program of interconnection or expansion which it was estimated would occur within a few years following the installation of the new machine.

Allowance must be made for the loss of the largest unit during operation and also for the possibility of its being out for repairs. If, therefore, units are purchased out of proportion to the size of the system there is likely to result an over-all economic loss. Large units show better performance at comparatively heavy loads. Due to the system reserve requirements it may be necessary to operate at a relatively light load where the economy is poorer. Even the smaller units operating may be affected the same way from the fact of the larger units being on the system. With large units the total amount of auxiliary power requirements for any given system output will also be increased at low system loads. With a large unit carrying heavy load a greater system disturbance would result if the unit should suddenly trip out. Other things being equal the time required for starting a large unit is greater than for one of smaller size.

Transportation difficulties for damaged parts, a longer time necessary for repairs, and larger floor area necessary for dismantling are some of the factors which must be weighed against the lower unit investment and lower labor charges.

Turbine manufacturers have indicated that up to 200,000-kw. capacity in single shaft machines would be feasible. By compounding on multiple shafts the limits, of course, would be considerably higher. One of the limiting features in size would be in connection with the generator and here the use of double windings or raising the voltage will offer a partial solution of the electrical problems.

The limitations to the building of large boilers are more structural than economic. Since at present larger capacity is concentrated in single turbines than in single boilers the problem of boiler reserve is of less importance. Also the experience with pulverized fuel boilers having capacities in the neighborhood of

1,000,000 lb. of steam per hour indicates an availability factor during demand periods approaching 100 per cent.

Large boilers have an exceedingly flat efficiency curve and can be operated at relatively low loads at efficiencies equal to that obtainable from boilers of smaller size. The parts involved in boiler construction are small and do not involve any transportation problems.

Rehabilitation of Existing Steam Plants

Many studies are still being made by steam station designers to increase station capacity by means of improved thermal cycles using higher temperatures and pressures, but not much actual revamping has taken place in the past year or so because of the falling off in power station demand and construction. Then again, while many studies of rehabilitation have been made, all recent improvements in steam station design have been quite broad in their application involving considerable major equipment. Generally speaking, where there has been a demand for increased capacity it has been for such large increments that invariably more consideration is given to the building of new stations with units of large capacity than to some modification of existing generating facilities.

Some steps looking to improved steaming have been taken, such as the installation of water-cooled walls frequently combined with pulverized fuel firing with resultant greater output from the same boiler; also, the installation of air-heaters resulting in a reduction of stack losses. Recent studies made on binary cycles indicate that improvements in efficiency can be made in old plants employing old boilers.

The important recent developments of interest to steam station designers both in the United States and abroad which will, no doubt, in the future have a great influence on rehabilitation, have been:

a. The installation of a 10,000-kw. mercury turbine in the South Meadow Station, Hartford, Connecticut.

b. The installation of high-pressure steam (750 lb.-2,800 lb.) units at Langerbrugge Power Station in Belgium.

c. The construction of new peak load plants in Germany of low pressures.

d. The construction of heat storage plants in Germany.

Rather than follow these lines of securing an increase in capacity and improvements of economy by changes in old stations, the trend in American practise is, with a few exceptions, more along the lines of building new efficient high-pressure steam plants and utilizing interconnections to a greater degree for permitting the operation of the new stations at high capacity factors on base load, and retaining the older less efficient stations for peak loads. With ample interconnections, addition of new capacity at old load centers is not often thought to be as economically advantageous, everything considered, as establishing new generating points where ample land, rail, and water facilities are available.

Reduction in Operating Costs of Steam-Electric Plants

The production of electricity from steam central stations has developed so remarkably in the last decade that it seems fitting in this report to review the progress that has been made during this time.

The average unit production cost has decreased about 50 per cent. The heat consumption per kilowatt hour has been reduced from about 30,000 B. t. u. in 1920 with a best record of 18,000, to an average of 18,500 B. t. u. in 1930 with the best record approximating 12,500 B. t. u. This is for stations using steam only. The mercury steam cycle installation at the South Meadow Station of the Hartford Electric Light and Power Company reports an average heat consumption of around 10,500 B. t. u. per kw-hr.

The progressive increase in the size of turbo generator and boiler units together with the improvements that have resulted in the reduction of supervisory requirements have brought about a constant decrease in labor costs. Great improvement has been made in control equipment with the consequent extension of the scope of supervision of individual operators.

Boiler maintenance costs have been reduced by the use of cooled furnace walls and from the studies by engineers of the effect of operating conditions on maintenance, with a consequent increase in availability of equipment.

Allocation of the load to various stations of a system on a basis which gives a minimum combined cost for each momentary change in load demand and at the same time taking into consideration the effect of loading on the maintenance of equipment, losses incidental to starting and labor costs, has brought about a great reduction in operating costs.

For example, for any particular load demand on the system there is one combination of units and loads at the various stations which will give the lowest combined cost for the system. The determination of this equipment set-up is made by grouping various combinations of units at the different stations through the use of cost input-load output and incremental cost characteristics of the units.

These cost input-load output and incremental cost characteristics are computed from tests on the equipment and it is very important that these tests be obtained with a high degree of accuracy. An operating factor based on a knowledge of the performance of the unit under normal conditions of operation is applied in order to obtain the true normal operating characteristic of the unit. The amount of equipment and location of equipment operating at the various stations must in all cases conform to the standard system operation reliability, which takes into consideration such factors as physical layout, storms, voltage regulation, and protection of the load.

With the determination of the amount of equipment operating at the various stations any change in system demand will be made on the basis of the station incre-

mental cost curves for the equipment operating to a point at which it becomes more economical to operate on another set-up. This method of loading for every momentary change in demand gives a minimum cost for all ranges of load, limits the number of units operating to those required for economy and reliability, and results in a greater utilization of the more efficient units.

In the case of one large power system during the last year the generating capacity of the system was increased about 2 per cent whereas the output delivered by the newer units was raised 13 per cent. As a matter of fact on that system during the year 1930 considerably more kilowatt hours were generated than in 1929 at a total production cost lower than that of 1929.

Table I shows the actual operating results obtained from several different types of stations. The low heat rate obtained by Station A indicates the possibility of a greater adoption of the mercury steam turbine in the near future.

River Rouge plant starts operation this year of the very interesting steeple compound 110,000-kw. turbo generator. The initial steam condition is 1,200 lb. at 750 deg. fahr. Live steam reheaters will raise the temperature of exhaust steam from the high-pressure element to 550 deg. fahr. at 80 lb. absolute pressure before it enters the low pressure element. Of particular interest is the fact that this new machine is installed in space originally occupied by two 12,500-kw. turbines and sufficient space will remain for the addition of a second 110,000-kw. unit of the same type at a later date. Two boilers, each having a maximum steam capacity of 700,000 lb. per hour, will serve this turbine.

The Port Washington plant will have one boiler of 690,000 lb. of steam per hr. to operate at 1,300 lb. pressure and initial and reheat steam temperatures of 825 deg. fahr.

In the realm of boilers for pressures above 1,400 lb. there has been no development except in that of size.

TABLE I—RECENT OPERATING RESULTS

Station	Pressure lb./sq. in.	Temperature deg. fahr.	Cycle	Load factor per cent	Period	Heat rate B. t. u./net kw-hr.
A	70	884	Mercury		Dec.-Feb. 1930	10,180
B	1200	750	Reheat regenerative	72.9	Oct. 1930	13,910
	350					
C	600	725	Reheat regenerative	65.5	Dec. 1929	12,455
D	1250	750	Reheat regenerative	52.0	Oct. 1930	14,091
E	600	725	Reheat regenerative	71.5	Oct. 1930	14,581
F	600	730	Reheat regenerative	62.7	Feb. 1930	13,368
G	400	725	Regenerative	54.8	Oct. 1930	16,290
	250					
H	400	700	Regenerative	59.3	Oct. 1930	15,712

Technical Developments in Steam-Electric Plant Design

The seven high-pressure stations described in the last report have been in operation long enough to confirm the results expected from them. Excepting continuing trouble with boiler feed pumps in some of the plants, no unsolved difficulties have been encountered. The more prominent additions to the list of high-pressure plants within the past two years have been the State Line plant near Chicago, the River Rouge plant of the Ford Motor Company in Detroit, and the Port Washington plant of the Milwaukee Railway and Light Company.

State Line plant, described in previous reports, was placed in operation in 1929 with a single three-element turbo-generator unit of 208,000-kw. capacity. The initial steam conditions were 630-lb. pressure and 730 deg. fahr. The extension to the plant now under construction includes two single shaft units of 150,000- and 125,000-kw. capacity respectively. The steam conditions will be 1,200 lb. and 825 deg. fahr., using boilers fired with pulverized coal from unit type mills. An interesting feature in connection with the turbines will be the reheating of steam from the high-pressure cylinder to 825 deg. fahr. at 400 lb. pressure, and its reintroduction into the high-pressure cylinder for expansion to the cross-over pressure of 15 lb. absolute. Reheating will be done in boilers of the reheat type.

The Benson and Loeffler boilers are now being built in Europe in capacities above 100,000 lb. of steam per hour; three Loeffler boilers, each with a designed output of 150,000 lb. of steam per hour at 1,850-lb. pressure and 932 deg. fahr. have recently been ordered for a plant in Czechoslovakia. The Benson boiler in use at the Langerbrugge plant in Belgium produces 220,000 lb. of steam per hour at 2,270-lb. pressure. An experimental boiler to operate at 3,200 lb. pressure, being installed at Purdue University, will be the first at that pressure in America. Boilers for 1,800 lb. pressure to supply steam to two 6,400-hp. triple expansion engines are now in course of erection at the Philip Carey plant in Cincinnati. The design of European types of high-pressure boilers was reviewed in the 1929 report.

There is some evidence that the average steam temperature in large power plants in this country has increased slightly during the past two years, and the maximum temperature in use is now considered to be approaching 800 deg. fahr. The Langerbrugge plant in Belgium has operated at a temperature of 850 deg. fahr., for 4½ years and in general there is more of a tendency to use extremely high temperatures in Europe than in this country. In certain respects modern European boiler designs lend themselves to the generation of high temperature steam, and the practise of multi-barrel turbines, common in Europe, is also

adaptable to its use. In the United States the Detroit Edison Company has recently put into operation a 10,000-kw. turbo generator at its Delray No. 3 plant, designed to use steam at 1,000 deg. fahr. At the present time the turbine is operating on steam from the station main under 400 lb. pressure and at 750 deg. fahr. For high temperature operation the supply steam will be passed through a separately fired superheater using oil for fuel. The steam main between the superheater and turbine is provided with several types of pipe joints, and other arrangements have been made to note the effect of the high temperature upon the piping, turbine, and superheater, so that the installation constitutes in reality a full scale experimental investigation.

During the past two years the mercury vapor boiler and 10,000-kw. turbine installation of the Hartford Electric Light Company has been perfected to the point where it was available for 82.3 per cent of a period covering 7,520 hours. Excluding causes arising from the use of mercury, the installation would have been available 95.1 per cent of the time. The average thermal rate was 10,310 B. t. u. per net kw-hr. Of the total energy generated, 42.5 per cent was produced by the mercury turbo generator, and the remainder by the steam formed in the mercury condenser.

As a result of the experience at Hartford, mercury vapor units of 20,000-kw. capacity each are being planned for the Kearney plant of the Public Service Corporation of New Jersey and for the power plant of the General Electric Company at Schenectady. The latter installation and an associated steam boiler will be one of the first outdoor steam plants. The mercury vapor pressure will be increased to 125 lb. per sq. in. in these new units, and it is expected that a thermal rate of 8,800 B. t. u. per net kw-hr. will be secured at a load of 20,000 kilowatts on the mercury turbine and with the power developed from the 240,000 lb. of steam per hr. produced at 400 lb. pressure in the mercury condenser.

Higher steam pressures and investigations of troubles resulting from caustic embrittlement have indicated the desirability of boiler drums without seams. Forged drums have been used exclusively for the 1,400-lb. boilers, and lately hammer-welded drums for medium pressure boilers such as the four drum boilers in the James H. Reed Station of the Duquesne Light Company in Pittsburgh, that operate at 400 lb. pressure. The possibilities of fusion welded boiler drums have been studied intensively in the past two years, and "Proposed Specifications for Fusion Welding of Drums or Shells of Power Boilers" were published in the March 1931 issue of *Mechanical Engineering*. The Boiler Construction Code does not at present permit fusion welding of parts where the safety of the structure is dependent upon the strength of the weld.

While no boiler installations have been made of larger capacity than those in the East River and Hell Gate plants in New York that were described in the last report, operating experience at the East River plant has shown that loads can be carried on the boilers there considerably in excess of the expected capacity. A unit generation of 1,250,000 lb. of steam per hour has been maintained, the actual operating limit being met in the capacity of the steam piping leading from the boiler unit. A boiler of 1,000,000 lb. per hr. capacity was recently installed in the Kips Bay plant of the New York Steam Corporation on a floor area originally allotted in 1926 for a boiler of half the output. These large boilers are in reality twin-set boilers having two independent water circulating systems and steam uptake connections, located over a common furnace. The largest single boiler to date has a capacity of about 600,000 lb. of steam per hour.

The installation of boilers of large capacity has focused the attention of operating and designing engineers upon the problem of boiler availability. Although in most plants the number of boilers still exceeds the number of turbo generators, boiler outage in many cases impairs to some extent a plant's generating capacity. Protection of the furnace walls with water cooling surface, improved reliability of the coal feeding and burning equipment, as well as of the ash handling apparatus, increased attention to the details of the auxiliary apparatus, and correct boiler water conditions, have resulted in numerous instances of boiler availability equal to that of turbo generators. The first statistical study of this subject on a large scale was directed in 1929 and 1930 by Mr. C. F. Hirshfeld of this Committee, and was published in *Transactions*, A. S. M. E., Vol. 52, No. 27, p. 265. The data compiled covered only a year and there were several other reasons why the statistics were necessarily inconclusive, but they seemed to indicate that the details of design and construction and operating skill are more important in obtaining high boiler availability than such matters as rate of output per unit of surface, type of fuel, and method of firing. The average availability factor appeared to be between 84 and 90 per cent.

During the period being reviewed, the point of major technical interest in connection with the pulverized coal method of combustion has been the long-time comparisons in the same plant of the unit and bin systems. No generally accepted opinion regarding their merits has been reached. Both systems were installed in the Deepwater plant, New Jersey, where it has been reported that the unit method of firing gave a higher efficiency but a lower reliability. Other comparative studies have been recently published for central stations in Chicago and St. Louis.

Experimentation has continued with the slag tap type of furnace for pulverized coal firing, and its use has been extended. The major difficulty has been the gradual expansion in a horizontal plane of the furnace floor, with consequent bulging of the furnace walls. This results from penetration of the hearth bed by the molten slag, through cracks formed when the furnace is cooled during boiler shutdowns.

The size and total fuel burning capacity of underfeed

stokers continue to increase, and steam outputs per boiler of 500,000 lb. per hr. are now possible with stoker firing. There has been only a foot increase in the maximum width of stokers in the last ten years, but the length has been increased from about 13 ft. to 26 ft. 7 in. The largest underfeed stoker in this country is now being installed in the Hudson Avenue plant of the Brooklyn Edison Company, and will be 26 ft. 7 in. long by 26 ft. wide, with a grate area of 694 sq. ft. Stokers of this size have been made possible by extensive cooling of the furnace walls by water cooled surface, improved coal feeding and distributing mechanism, and better control of the air distribution to the several parts of the grate surface and ash pit. In come cases automatic control of the air distribution has been installed. Rotary ash dischargers are almost standard for the larger size of stokers.

Although the fuel burning capacity of stokers per foot of width has been greatly increased, there has been no increase in the rate of combustion per square foot of total grate surface, which is limited by the possibility of clinkering and the blowing of coal from the firebed. Neither has there been any modification of the fact that the combustion rate depends upon the type or burning characteristics of the coal burned. Maximum rates of 60 to 70 lb. per sq. ft. for 10 hour periods have been maintained with good quality eastern coals; 50 to 60 lb. with coals from the central field. Slack coal reduces the maximum rate to the neighborhood of 40 lb. per sq. ft. With all coals an increase in the combustion rate results in an increased loss from incomplete combustion, cinders, soot, ash pit, radiation and unaccounted for losses, in some reported tests these losses reaching a value of 20 per cent.

The limiting temperature for preheated air with underfeed stokers seems to be in the neighborhood of 350 to 400 deg. fahr. Although some installations have attempted to use higher temperatures, it has been found that the stoker maintenance has been adversely affected.

The installation of large turbo generators has continued although no units have been projected larger than those mentioned in the last report. The largest machines now on order are two 160,000-kw. units for the Hudson Avenue plant of the Brooklyn Edison Company. It is noteworthy that all of the turbo generators except one, that are now on order in sizes greater than 100,000 kilowatts, are of the tandem compound type. The exception is the 110,000-kw. high-pressure vertical-compound machine for the Ford Motor Company. The development of generators of large capacity was an essential to the use of tandem-compound turbines.

The record in capacity for single cylinder turbines operating at 1,800 rev. per min. is now carried by two 80,000-kw. turbo generators in the Charles R. Huntley station of the Buffalo General Electric Company. Steam supply to these units is at 435 lb. and 750 deg. fahr.

In the field of high-speed turbo generators, single cylinder condensing units are now in operation in the United States up to 10,000-kw. at 3,600 r. p. m., and tandem-compound units at the same speed up to 15,000 kw. A 15,000-kw. single-cylinder condensing unit of English manufacture has recently been installed in Canada and the C. A. Parsons & Company are willing to build single-cylinder units of 25,000-kw. capacity to operate at 3,600 r. p. m.

Intensive study in turbine design is being made in connection with the use of higher steam temperatures. This problem as well as that of blade erosion is a matter of metallurgy, and the developments to date indicate that it will soon be possible to operate turbines at initial steam pressures above 500 lb. without the necessity of reheating. At the present time a 60,000-kw. unit has been built to use steam at 650 lb. and 825 deg. fahr., and illustrates the simplification and turbine arrangements that will be possible when higher steam temperatures are available.

High-Voltage Generators

There has been a significant demand for generator units of larger and larger capacities, and while this has possibly been the condition since the beginning of power station construction it appears to advance by periods with the most recent one occurring within the past five years. With an increase in generator capacity the designing engineers have been faced with the problem of providing suitable and reliable insulation, conductors, supports, and terminals both internal and external to the machines. Machines of larger capacity for a given voltage mean greater currents. Greater currents mean larger conductors, and consequently greater weights to support normally and greater stresses to provide for at times of short circuits. With the greater currents other external difficulties also arise, such as the provision for the installation of large cables if the power is taken away in underground cables, the reduced carrying capacity of the cables if many are required in restricted spaces, and the provisions necessary to nullify the effect of the sheath voltages. Consequently there has been a very natural trend to higher generator voltage and to multiple-winding machines to reduce the amount of current per conductor.

Unless it is necessary to consider generation at a pre-established voltage and the distribution problems connected therewith, in other words, if generation alone, is to be considered, the most economical voltage usually increases slightly with the increase in the size of the unit. From the generator manufacturer's standpoint, for generators of 100,000 kw. or more, voltages in the neighborhood of 16,000 to 18,000 volts are reported to result in the most economical design. In some instances, economics dictate machines within this range of voltage with transformers for stepping up to the desired transmission voltage, so that, where the generator voltages are not well established, it might be said that for machines above 100,000 kw., the present

trend is toward the use of multiple-winding machines with transformers or auto-transformers, rather than to higher voltage machines. The trend will no doubt continue toward multiple-winding machines until the point in capacity is reached when it will prove more economical to increase the voltage.

Some attempts have been made to standardize on generator voltages above 13,800 volts, but since the introduction of successful multiple-winding machines, the study and demand for higher standard voltages has not been so insistent, and may be said to be dormant for the time being. In other words, the double-winding design has made it possible to increase the capacity without increasing the voltage, and to postpone the day when it will be necessary to go to higher voltage. It is not at all unlikely that in the future, generators will be built with more than two windings. The principal difficulty with more than one winding, is in finding sufficient space at the terminals of the machine windings, to install potheads and make connections with satisfactory clearances.

Within the past three years there have been installed in the territory adjacent to Chicago, and there are now in operation, seven 22,000-volt generators with a combined generating capacity of 474,000 kw., ranging in size from 52,500 kw. to 105,000 kw. Additional 22,000-volt generators totaling 432,000 kw., and one 18,000 volt, 115,000-kw. generator are on order for this territory, to be installed during the years 1931-1932.

Outside of the above there have been but four steam-driven generators placed on order or installed recently in this country for voltage ratings above 13,800 volts, namely:

Two 160,000-kw., 16,500-volt units for the Brooklyn Edison Co., and

Two 94,000-kw., 16,500-volt units for the Southern California Edison Company.

Abroad, the outstanding recent high-voltage installations which will be watched with considerable interest are the two 33,000-volt, 25,000-kw., 3,000-r. p. m. generators at Brimsdown, England, and the 36,000-volt, 25,000-kw., 3,000-r. p. m. generator at Langerbrugge, Belgium.

Switch Structures, Switching, and Control

The housing of major switching in both congested and open localities is receiving much study, particularly new installations, because of the advent of metal-clad switchgear. There has been a marked increase in and trend toward the use of metal-clad switchgear in place of indoor cell type and outdoor open type bus structures. Many hundred indoor and outdoor type metal-clad combined switch and bus units of American design are now in service, some with air and some with oil-filled metal enclosed bus compartments.

The first installation in this country, and possibly in the world, of high-voltage outdoor metal-clad switchgear was the 33-kv. substation of the Public Service Company of Northern Illinois, at Wheaton, Illinois. This has been in service since March 1928. Since then there have been many other installations which embody improvements in design and manufacture. This type of switchgear can now be obtained in practically all capacities for which circuit breakers have been developed, including 132 kv. One 132-kv. installation is now being made. The earlier large units involved a considerable amount of field assembly. The latest designs permit complete factory assembly and testing of very large capacity units, such as a full double bus section for one circuit, complete with instrument transformers, buses, etc., for breakers of 22-kv., 3,000-amperes, 2,500,000-kva. interrupting capacity. These units are shipped completely assembled and oil filled thereby entailing a minimum of field assembly and installation work, and avoiding the necessity of drying out, reconditioning, etc., by purchaser.

In the case of several generating stations it has been found that an outdoor oil-filled metal-clad switchgear structure could be installed cheaper than an isolated or separated phase indoor cell structure if the cost of the building is taken into consideration; in some cases a saving as high as 20 per cent has been indicated. Other companies report the reverse where installation conditions are different. One company has proved by actual cost data that for 33-kv. substations the total over-all cost of metal-clad outdoor switchgear erected and ready for service, compares favorably with that of the conventional open type formerly used. This latter comparison, however, would not yet hold for all conditions and localities.

Additional advantages to be gained from complete factory built equipment are the saving in space, the salvage value in case of replacement or rearrangement, and the much greater safeguards to operators and service.

There is a growing demand for faster operation of circuit breakers in case of fault. The manufacturers have made considerable progress toward meeting this condition in the design of circuit breaker operating mechanisms and contacts and methods of extinguishing the arc as well as in the high-speed relay designs. Tests have shown repeated operations where the arcing time was as low as one to two cycles. Large breakers are now available with a conservative over-all time rating of eight cycles. In view of these developments it is quite possible a more severe duty cycle than the 2-OCO may be considered for the rating of oil circuit breakers.

The interest indicated in locating equipment outdoors is not confined entirely to switchgear. There are a few instances where large rotating units have been installed outdoors, and the subject is being given much study.

There has been an increase in the tendency toward the use of steel switchboard panels and the use of hinged panels or cubicals. The desirability of smaller switchboards in the larger power stations and substations is also receiving attention. Various attempts

have been made to use miniature equipment, and a smaller number of items, and combination units of instruments and relays. At the same time there is a growing demand for more relays and instruments for one purpose or another. The supervisory system of control seems to be arousing more and more interest as a means of condensing or consolidating the control of a large number of circuits within the convenient reach of a single operator.

The so-called distance relays are becoming more popular. The automatic synchronizing, automatic frequency, and automatic load division control are receiving more attention. Although the first has been available for a number of years, the latter are more recent developments and it is quite possible that the demand for both may grow.

If the predictions indicated in recent announcements with reference to vacuum tube developments, such as the "thyratron," may be anticipated, we are about to see some very wonderful and radical changes in the entire scheme of station control, switching, transformation, transmission and control station design in general. To what extent and how rapidly this may take place is at present problematical. The possibilities we must admit, however, are tremendous. Already there have been some novel commercial applications and very promising laboratory tests extending over a considerable period.

A new type of adjustable-speed control for a-c. motor drive is now available, permitting practically a straight line speed curve with infinitely small steps from zero to maximum. The drive can be installed at nearly the same cost as the drives previously used. The method of control permits high efficiency which in some cases shows a considerable saving over any other type of control. The drive will maintain constant speed regardless of load, is simple, permits the use of standard electrical design features, and to a considerable extent, standard machine parts. To date the service applications have been confined to boiler draft fans and boiler feed pumps, but the drive is adaptable to many other services where fine speed adjustments, and simplicity of operation with high efficiency, are important factors. Thirty-five of these equipments were ordered in 1930, some of which have now been in service for several months. For those who are not familiar with the "Rossman Drive" system it may be of interest to state it consists primarily of an induction motor of standard design, except that the mechanical construction is modified to permit what would be the stator to revolve. This revolving stator is connected by texrope or other means, to a smaller standard d-c. machine fed from a standard motor-generator set or other d-c. source. The speed of the small d-c. machine is controlled by adjusting the voltage impressed on its armature by the generator of the motor-generator set. This may or may not be supplemented by field control. By varying the speed and direction of rotation of the d-c. machine, the load may be driven at any speed within the design range.

Factors at Present Affecting Hydroelectric Development

The increasing attention directed to the large-scale hydro developments on the Colorado and St. Lawrence rivers by governmental agencies is perhaps a new factor influencing the trend of hydroelectric installations. At the same time the federal waterpower licensing policies are being questioned and subject to criticism by both private and political interests, and both have been coincident with severe drought during the past two years in many parts of the country. The complementary value of hydro and steam power sources on systems supplied mainly by hydro has been fully realized, and the principal hydroelectric systems on the Pacific Coast, in the southeastern states, in New England, and in the vicinity of Niagara Falls, have either put into operation during the last two years steam plants of large ultimate capacity or have affected large capacity ties with existing steam plants in adjacent territory. The recent availability of low cost gas and oil fuels in the West, and the advances made in the thermal efficiency of large boilers and turbines, combined with their attractive investment costs, are causing a pronounced predominance there of steam-electric installations that will continue for an unknown period. In the East and South the necessity of steam reserves for low-flow periods has accelerated steam expansion programs. At Niagara the entire water diversion permitted under the existing treaty is utilized and the load growth necessarily must be assumed by steam generation.

Type of Steam Plants on Hydroelectric Systems

A marked similarity in certain design features is noticeable in all of the new steam plants supplementing power systems hitherto dependent upon hydro generation. Gas and oil are the outstanding fuels in the West, while in the East pulverized coal exclusively is fired. Boiler capacities range from 400,000 to 550,000 lb. of steam per hr. at pressures between 425 to 475 lb. per sq. in. with the exception of one plant on the Pacific Coast operating at 1,300 lb. per sq. in. Turbine capacities vary from 40,000 kw. up to 100,000 kw., and one to three boilers are installed per turbine, the usual number being two. The selection of pulverized coal firing appears to be made for reasons other than the emergency starting of boilers; and in fact extra facilities for standby operation of turbines and boilers are provided in only one of the recent plants, which operates on a system where steam generation will be a minimum yet service demands require continuous availability of the steam-electric generator.

General Features of Recent Hydroelectric Development

No hydroelectric plants of unusual total capacities have been put into operation during the past two years, although there have been one or two new records for

turbines of large physical dimensions, and the three 49,000-hp. Francis units in the Waterville plant in North Carolina surpass in capacity all previous units of that type operating under high heads. An unusual construction procedure was adopted for the Chute-a-Caron plant on the Saguenay River in Canada. The preliminary drawings for the Boulder Dam plant on the Colorado River reveal no unusual features except the height of the dam and the contemplated power capacity. The Spier Falls plant on the Hudson River is an interesting example of rehabilitation and design investigation by means of model tests. In fact the increasing use of model testing, and its application to the design of the propeller type turbine wheel, constitute the outstanding technical advance in this country in hydroelectric practise during the past two years.

Propeller Turbine Development and Model Testing

Notable installations of propeller turbines of the fixed and manually adjustable blade types were in operation or approaching completion in 1928, and one small capacity wheel of the automatically adjustable type, the Kaplan turbine, was in the course of erection. Since 1928 there have been numerous installations in America of small capacity Kaplan type propeller turbines, that have been designed and installed under European licenses. The Kaplan turbine was first developed in Europe where there are now some large capacity wheels in operation. It is essentially suitable for low-head developments, being used for heads up to about 70 ft. European designs of the fixed blade and Kaplan turbines have been based upon extensive model testing of the turbine wheels as well as of the associated inlet casings and draft tubes.

One of the principal objects of testing models of propeller type wheels has been to determine the limiting conditions of cavitation, for which adjustable draft head conditions are required in the test laboratory. Cavitation, or the formation of bubbles of vapor and air in low-pressure areas adjacent to the runner surfaces, causes a drop of wheel efficiency, but its most prominent effect is the rapid disintegration of the runner material. Cavitation pitting had been encountered in this country with Francis type wheels under certain conditions of specific speed and draft head, and an amount of field experience has been accumulated by which proper operating conditions can be selected for Francis wheel installations. One of the chief advantages of the propeller turbine is the higher specific speed that is possible, but as field data were lacking for such operation, it was considered essential in Europe to determine the optimum installation conditions in advance of construction by means of cavitation testing. Following such investigations propeller turbines of record dimensions, horsepower, and water discharge capacity have recently been installed in the Ryborg-Schworstadt and Kembs plants on the Rhine River in Europe. Pertinent data about these plants are as follows:

Plant	Ryborg-Schworstadt	Kembs
Type of runner	Kaplan	Fixed blade propeller
Number of units	4	5
Head in feet	35	54
Turbine rating-horsepower	35,000	36,000
Water discharge-cu. ft. per sec.	10,500	6,800
Rev. per min.	75	94
Runner diameter-inches	276	220.8

Cavitation laboratories have been built during the past year, one or two in the United States and one in Canada, for the investigation of design problems concerning propeller type wheels. The construction of a national Federal hydraulic laboratory has also been recently authorized; model testing has been done extensively at one of the technical colleges in the United States for the design of dam spillways, water courses, and turbine settings, and two or three other colleges and individual companies have done a certain amount of such investigation. The first large plant in this country to install automatically adjustable blade propeller turbines is now being built at Safe Harbor on the Susquehanna River in accordance with data obtained from cavitation and wheel setting tests. Six turbines having a rating of 42,500 hp. each at a gross head of 55 ft. are being installed initially. The wheels will have a diameter of 220 in., a water discharge of 8,000 cu. ft. per sec. at rated head and output, and will operate at 109.1 rev. per min.

Briefly described the Kaplan turbine consists of a propeller, or axial flow turbine, whose blade angle is controlled by the speed responsive governor that controls the turbine wicket gates. Separate servo-motors are provided for operating the blades and gates, and a cam is used in the governing mechanism to direct the movement of the runner blades according to the movement or position of the wicket gates. The servo-motor for operating the runner blades forms part of the turbine shaft, and is usually located just under the generator coupling. The links and crank arms for moving the blades are enclosed in the runner hub.

By automatically maintaining the correct relation of blade position to gate opening, the peak efficiencies of a series of propeller wheels each having the proper blade angle for a particular turbine load, are secured, with the result that the efficiency-horsepower curve of such a turbine is quite flat compared to similar curves for fixed blade propeller and Francis turbines, the efficiency at low loads being materially higher. Another feature of the Kaplan turbine is the overload capacity possible by adjustment of the blades, which is of particular value in times of reduced head during high river stages. It is expected that the efficiency of the Safe Harbor turbines will exceed 85 per cent over two-thirds of the load range, and to equal 90 per cent or better for the third quarter of the unit capacity.

Rehabilitation of Hydro Developments

The 57,000-hp. unit recently added to the Spier Falls plant on the Hudson River, New York, exemplifies two distinct tendencies in hydroelectric practise, illus-

trating in addition to the use of model testing as a design adjunct, the recognition of the value of an overdeveloped plant for supplying peak-load capacity and the benefit derived from a storage resource by a run-of-river development. At full load the wheel discharge is 7,000 cu. ft. per sec., making it the largest Francis-type runner to date in this respect as well as in physical dimensions. The minimum regulated flow of the Hudson River at Spier Falls is 3,000 sec.-ft., and 5,000 sec.-ft. for 50 per cent of the time. Both the turbine and generator approach record sizes in physical dimensions, the total weight of the rotating element being about 450 tons. The generator stator is 37 ft. in diameter, and the diameter of the scroll-case entrance of the turbine is 26 ft. The unit operates at a speed of 81.8 rev. per min. under a head of 81 ft. Tests of a model of the forebay and intake structures enabled the best forebay outline to be determined with regard to amount of necessary excavation balanced against the head loss in forebay and intakes. The tests revealed that the area of the intake gates could be economically reduced 20 per cent, and this was of special value because the water passages are so large that they gave rise to structural design difficulties. It is reported that the tests resulted in a saving equal to ten times the cost of the tests.

High Head Plants

The Waterville plant of the Carolina Power and Light Company on the Pigeon River in North Carolina has an unusually high operating head, 840 to 750 ft., for a hydro plant in the eastern part of this country. There are three 49,000-hp. reaction wheels in the plant, operating at 400 rev. per min. and these are of record note for their capacity at such a head. The six-mile tunnel from the reservoir created by the dam to the power house is unprecedented even in the notable high head installations on the Pacific Coast. The use of cast steel butterfly valves of 9 ft. diameter under a total head of 840 ft. located in the penstocks near the power house, has been reported quite successful, and is an advance in the size of such valves under high pressure. Johnson valves are also provided in the penstocks where they enter the plant.

The record for large capacity high head Francis wheels will shortly be established in the Diablo plant of the City of Seattle, where two turbines of 90,700-hp. capacity each, to operate under a head of 327 ft. are being installed. The turbines will have cast steel scroll cases and concrete elbow draft tubes.

The record head, however, for Francis wheels occurs in a European plant, the Bringhausen plant in Germany, where four 40,500-hp. horizontal-shaft Francis turbines are being installed to operate under a head of from 950 to 1,000 ft. This is a pumped storage development mentioned later.

Large Scale Hydro Developments

The Beauharnois development on the St. Lawrence River in Canada is notable for the ultimate capacity being planned when the entire flow of the river passes to the power house through the combined navigation and power canal connecting two of the lakes on the flow line of the river. The initial section of the plant will contain ten 50,000-hp. units, to operate under a head of 83 ft. The final capacity will be 2,000,000 horsepower. The construction of the canal between lakes St. Francis and St. Louis, which will be 15 miles in length with a width of 3,000 ft. and a depth of 27 ft. is outstanding because of its magnitude rather than any engineering difficulties.

Another plant that illustrates the scale of development possible on some of the rivers in Canada is the Chute-a-Caron plant on the Saguenay River where four 65,000-hp. units have been installed as the initial step of the future Shipshaw plant of 1,000,000 horsepower. The Chute-a-Caron dam will serve to divert the river for later construction of the Shipshaw plant, but because the head at Chute-a-Caron is only 151 ft. as contrasted to that of 205 ft. at the parallel site, the Chute-a-Caron plant will be operated in the future only during river flows sufficient to supply both plants. The difficulty of construction in the gorge of the Saguenay River is thus being solved by the step-by-step development at the two neighboring plant locations. The river was diverted in a unique manner for the construction of the Chute-a-Caron dam by toppling a concrete cofferdam 92 ft. long into the swiftly flowing current, which caused the flow to pass into an artificial channel previously prepared. The action of the concrete monolith weighing 11,500 tons was accurately predicted by means of model tests.

Storage Developments

The largest hydroelectric plant in New England has been recently completed at Fifteen Mile Falls on the upper reaches of the Connecticut River, in conjunction with the first 220-kv. transmission line in New England. The plant is designed for four 53,000-hp. units at 175-ft. head, and is the first development at two nearby sites which will eventually have a total combined rating of 300,000 horsepower. The completion of the second plant will create a reservoir for regulating the river flow not only for the plants at Fifteen Mile Falls, but also for the plants at Bellows Falls and Vernon, farther down the river. The 220-kv. line carries the output of the plant to a distributing point in the vicinity of Boston.

The Osage plant at Bagnell, Missouri, now approaching completion, will contain six 33,500-hp. units operating under an average head of 90 ft. Without storage this plant would not be feasible since the river flow varies from 324 to 110,000 cu. ft. per sec. with an average of 10,500 sec-ft. The dam will create a reservoir 95 sq. mi. in area having an impounded volume of 87 billion cu. ft., so that the flow of the river will be completely equalized with a draw-down of 30 feet. The average yearly energy available will be about 400 million kw-hr. The Osage plant is also a late example of the omission of a superstructure over the

generator bay, the station crane having one gantry leg while the other end of the crane rests on top of the outer wall of the electrical bay which is placed over the penstocks between the dam bulkhead and the generator bay. Low metal housings are provided over the tops of the generators.

The Saluda storage development in South Carolina, described in the last report, was placed in operation last year and is notable for its reservoir capacity of 102 billion cu. ft.

Outdoor Type Plants

The omission of the generator room superstructure continues both for small plants of a single unit and for plants of large installed capacity. Generator designers are predicting that the flexibility of design now possible with fabricated construction, and the latitude permissible in the layout of auxiliary power and excitation systems, will lead to the arrangement of generators to conform to the design of the power house, and that the logical outcome may be the wider use of outdoor generator designs.

Pumped Storage Plants

No installations of pumped storage plants in America have followed the completion of the Rocky River plant in Connecticut, although the use of pumped storage continues popular in Europe where electric system peaks are of shorter duration than in this country. One illustration is the Bringhausen plant on the Weser River in Germany, now under construction, which will contain four combination pump and waterwheel units, each consisting of a 40,500-hp. Francis type horizontal turbine coupled directly to a 36,000-kva. generator, on the other side of which is a clutch for coupling to a 100,000-gal. per min. pump requiring 29,000 hp. for pumping. The plant is connected to an upper reservoir at an elevation 1,000 ft. higher by two penstocks 3,250 ft. in length. The water to be pumped to the reservoir amounts to 26,800,000 cu. ft., from which 500,000 kw-hr. will be generated. Power for pumping during off-peak hours is obtained from interconnected steam plants and other hydro plants on the system.

The horizontal coupling of a pump and a turbine with a generator and/or motor seems to be the preferred arrangement for pumping plants in Europe, and is in contrast to the Rocky River plant layout of pumping units with individual drive motors separate from the main turbine and generator, all of the equipment being of vertical type. The Rocky River pumps which are the largest high-head pumps in this country, have a volute discharge casing without diffusion vanes, and are of the single inlet type. On test the Rocky River pumps showed a maximum efficiency of 91.7 per cent; the efficiency expected by the designers of the German pumps is approximately 80 per cent.

Hydroelectric Generator Developments

There has been a widespread adoption during the past two years of fabricated steel plate construction of both stator and rotor of vertical waterwheel generators, in place of the use of castings formerly standard. Such generator construction of welded steel plate is lighter in weight, is considered to be more reliable mechanically, and is more adaptable to design arrangements. There has been an increased use of the umbrella, or overhung type of generator rotor, in which by means of downwardly curved rotor arms the centerline of the rotor rim or pole faces is brought below the horizontal centerline of the hub. By locating a combined guide and thrust bearing, sometimes of the spherical type, just below the rotor hub, a very material reduction in over-all generator height is secured. The use of rolled steel plates and fabricated construction for the stator has also facilitated the arrangement of ventilating ductwork in connection with the water tube air coolers that are now used very largely for generator cooling. Other advantages of fabricated plate construction are quicker manufacture and possibility of design for shipment without restriction by permissible weights or clearances.

Acknowledgments

This report has been compiled by a subcommittee, the members of which respectively prepared the several sections as follows:

F. A. Allner, Hydroelectric Topics; N. E. Funk, Major Influences in Current Design of Steam-Electric Plants, and Factors at Present Determining Maximum Size of Boilers and Turbines; F. H. Hollister, Rehabilitation of Existing Steam Plants, High-Voltage Generators, Switch Structures, Switching, and Control; H. W. Leitch, Reduction in Operating Costs of Steam-Electric Plants, and Technical Developments in Steam-Electric Plant Design.

The subcommittee wishes to express its appreciation of the helpful suggestions received from the main body of the Power Generation Committee.

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†Hydraulic Division.

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Power Transmission and Distribution

ANNUAL REPORT OF COMMITTEE ON POWER TRANSMISSION AND DISTRIBUTION*

THE Committee has continued with its work during the past year through a number of subcommittees organized as in preceding years. All of these subcommittees have been very active in studying the problems in their respective fields, and in promoting investigation work and the preparation of papers for presentation before the Institute. The reports of the work of the several subcommittees follow.

Subcommittee on Distribution

One of the most interesting developments in connection with the distribution of electrical energy during the past year has been the practical application of the network principle to primary distribution. The economies and improvements to service which are made possible through the adoption of the low-voltage network have been so clearly demonstrated by the generally satisfactory performance of the many recent installations, that a wider application of the principle is not surprising.

At the present time there is being installed a 4-kv. primary network in Pittsburgh, Pa. This will serve a residential district of comparatively low-load density which was previously served by an overhead radial system.

The application of the network principle to 4-kv. service for such an area requires certain radical departures from the designs which have become fairly well established for distribution. Since underground construction in the areas of low-load density is not usually justifiable from an economic viewpoint, overhead construction must be used. The primary network deserves careful consideration from the standpoint of economy, reliability, and system planning in handling loads in areas not readily adaptable to low-voltage network distribution.

The past year has seen a continued application of vertical network distribution in large office buildings. This type of distribution has been used in a number of large cities including New York, Pittsburgh, and San Francisco. At the present time several features of design have not been settled. These features are being given consideration and it is expected that with the extended application of the vertical network principle a better understanding of them will result.

The question of secondary faults on low-voltage a-c. networks is still being discussed at length. There is a feeling among some engineers that the problem is not radically different from that encountered on the d-c. network. Others feel that short-circuit currents available are generally less and the condition is therefore more difficult. The use of buried cable has also been studied and tests made which will be reported in the near future.

Subcommittee on Lightning and Insulators

Past Year's Activities in Investigation Work

The activities in the field of lightning investigation during the past year have been carried on by means of:

1. Field investigation of natural lightning.
2. Field investigation with artificial lightning.
3. Collection of operating data on lightning performance of lines.
4. Theoretical analysis and coordination with the past lightning data.

In the field investigations, use was made of cathode-ray oscillographs, klydonographs (and surge recorders), surge indicators, lightning intensity recorders, direct-stroke recorders, and artificial lightning generators. This year the field investigation was extended to include a wood-pole line on which was recorded lightning voltages in the order of 5,000,000 volts.

By concentrated efforts in the field with the artificial lightning generator, a vast amount of knowledge has been gained on the effect of tower footing ground resistance, counterpoises, effect of normal voltage in sustaining a power arc in the presence of lightning flashover of a line, and particularly on the operation of the lightning arrester.

The behavior of traveling waves at the junction of cables with overhead lines was further studied by the use of the artificial lightning generator with particular attention to the application of lightning arresters.

Extensive use was made of the lightning (direct) stroke recorder and our knowledge in regard to the

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current in direct strokes amplified, and made more definite.

The cathode-ray oscillograph application was modified to trace the history of a natural lightning wave over a period of some 2,000 microseconds, in addition to recording the initial characteristics of the waves.

Surge indicators were used for the first time, although mentioned in last year's report. These definitely established the fact that a lightning flashover of a transmission line can take place without sufficient follow-up current flowing to trip out the line.

The past year has brought out some intensive study of a theoretical nature on the lightning problem dealing with the mechanism of the lightning stroke and the subsequent surges which may appear on a transmission line. Both the direct stroke and induced stroke have been analyzed and the conclusion pointed out that only direct strokes appear to have consequential effect on the highly insulated lines, while medium and lower insulated lines will be affected in an increasing order by induced strokes.

Results of Last Year's Work

It is impossible here to point out in detail all the results of last year's investigation. There are, however, some outstanding accomplishments, among which the following are cited.

1. The effectiveness of ground wires in reducing lightning voltages and line outages has been further demonstrated.

2. The value of low tower footing resistance in lessening the effects of lightning voltages has been shown.

3. Currents in the lightning stroke in the order of from 50,000 amperes and upwards have been indicated.

4. Counterpoises at a tower footing, even although of comparatively short length are beneficial in reducing the lightning voltage to which a line may be subjected.

5. Lightning sparkover of a line can take place without power follow current.

6. Lightning voltages of both direct and induced stroke origin appear to be present on transmission lines. It is not known in what normal insulation and voltage range the induced voltage ceases to be a factor in line flashover.

Insulation Coordination

In order to coordinate insulation on a lightning basis, its lightning characteristics must be known. Whether these are secured on a single impulse wave or voltage time lag basis, a standard test method must be agreed upon by all who supply this type of data. The Committee has this matter well in hand at the present time, with the probability that an agreement will soon be reached by all actively engaged in this work whereby a group of two or more preferred waves will be used for securing this type of data.

Insulator Flashover Values.

It has been known for some time past that discrepancies have existed in 60-cycle flashover values assigned to insulators of practically the same physical dimensions. The cause for these different flashover values has been traced to a variation in humidity conditions at the time and place of test. A great deal of experimental work has been done on this problem, and it is expected the information obtained will soon be made public through a group of papers before the Institute.

Subcommittee on Interconnection and Stability Factors

In order to coordinate the work of the Power Generation Committee, the Protective Devices Committee and the Power Transmission and Distribution Committee in the field of interconnection and system stability, there has been formed a Joint Interconnection Subcommittee. This Subcommittee was organized during the year and has arranged several sessions of interest in the field of transmission and distribution. These include the session on System Grounding at the Pittsburgh Meeting in March 1931 and the session on System Interconnection for the Summer Convention of 1931. In addition, plans are under way for a symposium at the Winter Convention of 1932 on the subject of Machine Characteristics and System Stability. In last year's report mention was made of the organization of a Subject Committee on Definitions of Terms Used in Stability Investigations. The work of this Subject Committee is now substantially complete and it is planned to present it as a paper at the Winter Convention in 1932.

Subcommittee on Cable Developments

This year has witnessed the continued practically universal use of shielded cable (type H) for all three-conductor high-voltage cables. Other tendencies are the increased use of oil-filled cables, the use of super-calendered paper, a great increase in the use of non-metallic armored cables for direct burial in the ground for low-voltage work, and the use of steel-wire armored, non-leaded cables for submarine service and for vertical distribution cables in high buildings.

The Following Cable Installations May Be Noted:

1. A second circuit, 175,000 kva. (winter rating), of single-conductor 132-kv. oil-filled cable about 6 miles long by Commonwealth Edison Co. in the same conduit bank as their first circuit. The new circuit has 1,100,000 cir. mils conductors as compared with the 600,000 cir. mils previously used. The larger conductor size is made commercially feasible by insulating sleeves and grounding devices to eliminate sheath losses. Due to the many improvements in accessories and technique, the net result was that the investment cost per kva. of capacity is less than one-half the cost of the first line.

2. Two lines of single-conductor 600,000-cir. mil 132-kv. cables each three-quarters of a mile long installed by the Commonwealth Edison Co. one (90,000 kva. rating) similar to the cable of paragraph 1 above, and the other (95,000 kva. rating) with novel features of oil channels cut in the interior of the lead sheath as well as an oil channel in the conductor, a simple and small stop-joint, making it possible to have every joint a stop-joint, which joint is practically a factory-made and factory-tested joint.

3. The Deepwater installation of the United Gas Improvement Co. across the Delaware River consisting of two 60,000-kva. circuits (and two spare cables) of single-conductor 750,000-cir. mil 75-kv. solid type cable manufactured and installed in single lengths each about 4,000 ft. long. These are the first 75-kv. submarine cables and longest lengths of power cable ever manufactured.

4. Two circuits rated at 55,000 kva. each of single-conductor 750,000-cir. mil 75-kv. solid type submarine cable of the Union Electric Light and Power Co. of St. Louis across the Mississippi. The cables were made and installed in single lengths of about 2,800 ft. each.

5. An installation of five three-conductor 48,000-kva. 66-kv. oil-filled cables by the Union Gas and Electric Co. of Cincinnati. This is the first three-conductor 66-kv. oil-filled cable, and is buried direct in the ground. The conductor size is 500,000 cir. mils sector, insulated with 0.40 in. impregnated paper and shielded. The cables are made in single lengths 1,300 ft. long, thus avoiding joints, and are steel-tape armored cables buried directly in the ground.

6. Three commercial installations have been made during the year of three-conductor 33-kv. to 35-kv. oil-filled cable, although the amounts were rather limited. These installations were made by the city of Los Angeles, the Staten Island Edison Co., and the Syracuse Lighting Co. All three installations were made with three-conductor type H cable with oil channels in the filler spaces. A novel feature was the three-conductor positive stop-joint by the city of Los Angeles, and also the fact that a large installation of cable with oil channels in the filler spaces including a more viscous oil was installed by this company, who after installation replaced the oil in the channels by oil of the type used in oil-filled cables.

7. An experimental installation of single-conductor 132-kv. oil-filled cable by the Commonwealth Edison Co. of Chicago in cooperation with two manufacturers, each of whom supplied 1,000 ft. of 450,000-cir. mil or 500,000-cir. mil cable insulated with 0.40 in. paper and 1,000 ft. with 0.50 in. paper. The purpose of this experiment is to study the limiting stresses and temperatures in oil-filled cable for present and future voltages.

8. An experimental installation of single-conductor 132-kv. cable by the Public Service Electric and Gas Co. as a continuation of their 1927 experiment studying the possibility of "solid type" insulation for 132-kv. service. The installation consists of three cables each of 500,000 cir. mils and 1,000 ft. long, two supplied by one manufacturer and one by another. Each manufacturer supplied a length of solid-type cable. The third cable is of an intermediate or hybrid type, using oil intermediate in viscosity between that of an oil-filled cable and of the usual type of cable, thus greatly facilitating installation methods while sharing in part the operating advantages of an oil-filled cable.

The Subcommittee on Conduit and Manhole Temperature of the N. E. L. A. Underground Systems Committee has standardized on conditions and constants for calculating current-carrying capacity. This standardization has made it possible to calculate current-carrying capacities of cables covering a large range of sizes and conditions. These tables of carrying capacities will be published by the Underground Systems Committee, and should prove of great value to the industry.

Subcommittee on Steel Transmission Towers and Conductors

The Subcommittee on Steel Transmission Towers and Conductors was organized to assist in the standardization of steel transmission towers and conductors by clarifying the problems associated with their design and application, by papers prepared by recognized authorities on these subjects and presented before the Institute.

The work of the Subcommittee has been divided into three groups, each of which is responsible for one of the following subjects:

I—Towers.

II—Clearances and Electrical Characteristics.

III—Conductors.

During the past year, four meetings of the Subcommittee have been held, together with some additional meetings of groups within the Subcommittee.

An addition to the clause of the N. E. L. A. specifications on uplift of tower foundations and a recommendation for a straight line compression formula for the N. E. L. A. specifications is in course of preparation. Consideration is being given to elimination of the term "factor of safety" by substituting therefore "per cent overload." Contact is being maintained with the A. S. T. M. on its investigation of embrittlement of hot dipped, galvanized steel.

It is proposed to recommend that the 60-cycle flashover be the basis for clearance of the tower under winter or heavy loading conditions and that lightning flashover be the limit for summer or light loading conditions. The width of the right-of-way is to be limited by similar conditions.

Intensive study is being given to the vibration of conductors. Efforts are being directed principally to the coordination of experimental work being done by widely separated investigators, including California, Texas, Illinois, Michigan, Ontario, England, and Australia. A bibliography is being established as an adjunct to this work.

The present membership of this committee, including

the chairman, is now twenty, with five men in Group I, six men in Group II and eight men in Group III.

It is felt that the work of this subcommittee is now progressing smoothly and during the next year, concrete results can be shown as the result of its activities.

Conclusion

For the sake of brevity, this year's report excludes the bibliographies of papers which appeared in last year's report. It is planned to include such bibliographies in the Annual Report at appropriate intervals, rather than every year.

In conclusion, it is desired to stress the conscientious and enthusiastic work of the chairmen and members of the subcommittees to whose liberal contributions of time the progress made is due.

Transportation

ANNUAL REPORT OF THE COMMITTEE ON TRANSPORTATION*

YOUR Committee on Transportation submits a brief review of the recent developments of importance in the application of electricity to transportation.

Steam Railroad Electrification

Pennsylvania Railroad

The Pennsylvania Railroad has been actively continuing its electrification program. On June 29, 1930 electric operation was inaugurated between Philadelphia and Trenton, N. J., a distance of about thirty miles. On July 20th, electric operation was started between Philadelphia and Norristown, Pa., on the Schuylkill Division, seventeen miles. Fifty-nine multiple unit cars have been recently acquired. This installation completes the suburban electrification about Philadelphia. Distribution of power is at 11,000 volts, 25-cycle, single-phase. The equipment for suburban service is at present all motor cars, with multiple unit control.

The new suburban terminal at Broad Street was opened on September 28th. This is of necessity, entirely electrically operated, for the tracks are, like those of the passenger terminal at New York, under cover. The new suburban station at Thirtieth Street on the west bank of the Schuylkill River was also placed in service at this time. This will ultimately be an integral part of the Pennsylvania Terminal at West Philadelphia now under construction.

The Pennsylvania Railroad now has in electrified operation about Philadelphia, 132 miles of route and 437 miles of track; 345 multiple unit cars are in service.

Work is actively progressing in the New York Terminal zone preparatory to changing from the 600-volt third rail to 11,000-volt, single-phase trolley wire between Sunnyside Yard and Manhattan Transfer. This installation, which will among other things allow New Haven locomotives to enter the Manhattan Terminal, should be completed during the present year.

Construction is progressing between New Brunswick and Manhattan Transfer and will shortly be started between New Brunswick and Trenton, and between Wilmington and Washington.

Four types of locomotives are being developed for the complete electrification. Two passenger types, one freight and one yard switching. The light passenger type (designated as 0-1) is of 2-B-2 arrangement, and two of these units will be used on the heavy passenger trains. The heavy passenger type (P-5) is of the 2-C-2 arrangement. The freight type (L-6) is of the 1-D-1 arrangement. The passenger locomotives will use twin motors rated at 500 hp. per armature, or 1,000 hp. per axle. The freight locomotive will be equipped with four motors of single armature type, and will thus have a rated capacity of about 2,000 hp.

Long Island Railroad

The multiple unit suburban service of the Long Island portion of the Pennsylvania Railroad, operated by third rail distribution, is rapidly growing. Eighty-five multiple unit cars now being added to the equipment, bring the total number of cars to 825. To provide power for the increasing load, the Floral Park, substation is being remodeled and will be equipped with two rectifiers of 3,000-kw. capacity. Four new substations—Hempstead, Manhasset, Rockaway Park, and Goose Creek—are being built, in addition to four planned for installation next year. Each of the new substations will contain one 3,000-kw. mercury arc rectifier, except at Goose Creek where portable synchronous converter equipment will be installed. The rectifiers will be adapted for 60 or 25 cycle operation, an external reactance being added for the lower frequency.

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*COMMITTEE ON TRANSPORTATION:

Sidney Withington, Chairman,

P. P. Ash,	K. T. Healy,	A. S. Richey,
R. Beeuwkes,	D. C. Jackson,	S. A. Spalding,
A. E. Bettis,	J. Murphy,	N. W. Storer,
J. V. B. Duer,	I. Ofverholm,	W. M. Vandersluis,
H. H. Field,	H. Parodi,	R. H. Wheeler,
I. W. Fisk,	W. B. Potter,	R. P. Winton,
W. A. Giger,	R. H. Price,	G. I. Wright.

Delaware, Lackawanna & Western Railroad

The suburban electrification of the D. L. & W. R. R. was inaugurated between Hoboken and Montclair, N. J. on September 3, 1930, the service to South Orange, N. J. September 22, 1930 and that to Morristown, N. J. December 18th. The present electric installation was completed with the electric operation in January 1931 to Gladstone and Dover, N. J. This electric operation comprises about sixty-eight route miles and one hundred and fifty-eight miles of track; and includes 282 multiple unit cars. These cars operate in pairs, the units consisting of one motor car and one trailer each. Five substations, each containing mercury arc rectifiers, furnish the distribution power at 3,000 volts direct current. Two electric three-power locomotives (oil, storage battery, and trolley operated) have been acquired and are used for switching and transfer service between Jersey City and Secaucus freight yards. The D. L. & W. is the first heavy traction service in this country to utilize 3,000-volt direct current on motor cars, and the first to install exclusively mercury arc rectifiers.

New York Central Railroad

The Cleveland Union Terminal electric operation was inaugurated June 28, 1930. This project comprises 17 miles of route and about 60 miles of track, between Collinwood and Linndale, Ohio, and employs twenty-two locomotives. These locomotives are 2-C + C-2, weighing about 204 tons, of which 150 tons is on drivers. They are designed for a maximum speed of 70 mi. per hr. The locomotives are used interchangeably for switching or road service. Train heating boilers, oil-fired, are provided on the locomotives. The power distribution is by means of 3,000-volt direct current, using a catenary system. This is supplied from two substations, one 3.5 miles west, and the other 7.2 miles east, of the Union Station; each equipped with motor-generators, remotely controlled from the terminal building by a supervisory system of the synchronous selective type. The installed capacity is 9,000 kw and 6,000 kw. respectively.

The New York City electrification of the New York Central is progressing. The "West Side" tracks will be electrified by the middle of the current year as far south as Seventy-second Street, the tracks north of that point being on a viaduct, or on private right-of-way. Forty-two freight locomotives have been purchased for this service. Distribution of power is by direct current at 650 volts using a third rail. South of Seventy-second Street the tracks are on city streets, and the operation will be accomplished by three-power (oil-electric-storage battery) locomotives, of which the railroad has purchased thirty-five.

Reading Railroad

The electrification of the Reading Railroad at Philadelphia is progressing, and operation should be started about the middle of the current year. This project includes about 69 route miles and 161 miles of track; seventy multiple unit cars will be operated initially. The distribution system is at 11,000 volts, single-phase, 25 cycles.

Great Northern Railway

The Great Northern Railway has placed in service four new motor-generator locomotives with axle arrangement 1-C + C-1, essentially similar to those of that type already in operation. Each locomotive weighs 263 tons, of which 210 tons is on drivers. The distribution of power is at 11,000 volts, 25 cycles, single-phase.

Illinois Central

The Illinois Central Railroad placed in service in 1930, four 100-ton straight-electric locomotives for switching service, and also five 600-hp. oil-electric locomotives of the Diesel type. The motive power now in suburban service consists of 280 multiple unit cars, 140 of which are motor cars and 140 are trailers. In the freight switching service, there are now four straight-electric locomotives and six 600-hp. oil-electric. The power distribution is 1,500 volts, direct current. About 154 track miles are electrified.

New York, New Haven and Hartford Railroad

The final extension of the New York, Westchester and Boston Railway to Port Chester, N. Y. was completed late in 1929. The New York, Westchester and Boston—an integral part of the New Haven electric operation, now operates from Harlem River to Mount Vernon, N. Y., with branches to White Plains, N. Y. and to Port Chester, N. Y. The total New Haven a-c. electrified mileage is now about 577 track miles, over approximately 116 miles of route. The road operated, as of the end of 1930, 141 electric locomotives and 267 multiple-unit cars. The New Haven last year placed in service nine multiple-unit cars. During the current year there will be added to the equipment, ten 200-ton passenger locomotives and 33 multiple-unit cars. The power distribution of the New Haven is at 11,000 volts single-phase, 25 cycles, but the passenger motive power is designed to take power also from the New York Central third rail at 650 volts, direct current.

Substations for Electrified Railroads

The conversion of power for distribution on the Delaware, Lackawanna and Western electrification is, as previously noted, entirely by means of mercury arc rectifiers. This installation consists of 18 units in 5 substations with a total capacity of 40,000 kw. The rectifiers are also provided with a means of compounding, so that voltage can be maintained over a fairly wide load range at substations. Reference is made to the report of the Technical Committee on Automatic Stations covering this feature. Four of the substations are manually operated but are provided with many of the usual automatic protective features. One sub-

station is completely automatic. Remote and supervisory control are provided for the automatic substation and the tie stations.

In its electrification the Pennsylvania Railroad has continued with the 11,000-volt distribution system now in use on other parts of its system involving step-down transformer substations installed at intervals of 7 to 8 miles. The Reading electrification consists of the three-wire distribution system with 11,000 volts on the trolley and a feeder of 33,000 volts. Auto transformer stations are used at intervals, to transfer energy from the 33,000-volt feeder to the 11,000-volt trolley. Some of the substations of the Pennsylvania Railroad electrification are remotely controlled from adjacent signal towers, and those of the Reading are controlled by supervisory control so that the power director indirectly or directly has control of all circuit breakers within his jurisdiction.

The Cleveland Union Terminal Substations contain two and three 3,000-kw. motor-generator sets respectively, with complete automatic control. A synchronous selective supervisory control system with remote telemetering provides the dispatcher, located in the Terminal Building, with complete supervision and indication of the substation, feeders and tie station.

High-speed air circuit breakers have been employed in all substations of the d-c. systems mentioned above, and the Pennsylvania Railroad and Reading Railroad a-c. systems have employed high-speed a-c. breakers of the air and oil type. Reference is made to the report of the Committee on Protective Devices for data regarding the various types of high-speed circuit breakers available for a-c. and d-c. service.

Electric Locomotives

A novel development in the field of a-c. locomotive design has occurred abroad. In this design the low-voltage terminals of the transformer are permanently brought out, and all voltage control for the motors is by means of an oil-immersed tap changer and air switches from the high-voltage windings. The arrangement is a development of the growing use of the scheme of "tap-changing under load" and if it is found to be practicable under service conditions, should materially simplify the design of a-c locomotives.

A novel development in electric locomotive design has been accomplished in the new locomotive of the Illinois Central Railroad. This compensates the tendency of reduced weight upon the forward drivers at high drawbar loads, especially at starting, on account of the moment of the drawbar pull and rail reaction. The arrangement consists of shunts for weakening the field of the leading motor of each truck, which reduces the tractive effort of the leading motor and increases that of the rear, in proportion to the field strengths of the two motors. The forward drivers thus show less tendency to slip and the drawbar capacity is therefore increased.

There has been a number of notable improvements recently in the design and construction of the single-phase motor which have materially decreased its weight per horsepower and have improved efficiency and power factor. Attention is called to the report of the Committee on Electrical Machinery for descriptions of these developments.

Oil-Electric Locomotives

In addition to 35 oil-electric-storage battery locomotives acquired by the New York Central Railroad for the "West Side" operation in New York City, seven similar units have been placed in service in Chicago, and as above stated, two on the Delaware, Lackawanna & Western Railroad. The Canadian National last year acquired a Diesel locomotive, as have various industrial concerns.

A novel arrangement of Diesel locomotives has been developed, wherein the engineer's driving position is raised to a sort of mezzanine floor, so the engineer may look over the top of the train he is moving. In this design, controllers, air brake handles, etc., are provided at both sides of the cab so the driver may move from side to side as desired to observe signals from the switching crew.

Rail Cars

Fifty-six rail cars of gasoline and oil electric design were produced in this country during the past year. As an indication of the increasing use of this type of equipment in heavier service, the average power of these cars was about 450 hp. as compared with about 350 hp. the average in 1928.

Marine Transportation

A number of turbo-electric and Diesel-electric vessels of various types was produced in 1930. The *S. S. President Hoover* is the largest electrically driven liner produced thus far. The propelling equipment consists of two 14,000 hp. turbines with three-phase 10,100-kw. generators, and two 13,250-hp. synchronous induction motors. Auxiliary electric apparatus on steam and Diesel propelled craft has developed in a number of different directions, replacing steam auxiliaries. Attention is called to the report of the Technical Committee on Application of Electricity to Marine work.

Aviation

A number of electrical devices has added to the art of aviation during the past year. Among these is the "turn compensator," an electrically driven device to correct the error experienced in all types of "earth inductor" compasses when the direction of the ship is suddenly changed. This device may also be used as a "turn indicator" to show quickly and with reasonable accuracy the angular change in direction.

Recently developed engine-performance indicators, electrically operated, showing oil-pressure, oil-temperature, speed, etc., are of value especially on multiple-engine ships, by permitting remote indication.

In the field of illumination for aviation, wing-lights set into the leading edge of plane wings increase efficiency by reducing non-productive air resistance. Airways are being illuminated by increasingly powerful and efficient beacons. The illumination of landing fields by means of flood lights and marking lights is keeping pace with other developments.

Railroad Signaling

Centralized traffic control by means of coding systems is rapidly being extended on railroads. This enables a dispatcher or tower operator to remotely control switches and signals over a large territory and thus direct trains quickly and effectively without the necessity of train orders.

Urban Transportation

The chief developments in urban transportation are efforts to obtain faster car acceleration, higher speeds, and better braking, to compete with increasingly difficult traffic conditions. The increased use of double-reduction and worm gears has made the operation of higher speed motors practicable with marked decrease in weight (especially in unsprung weight). Lower floors, with greater speed in loading and unloading, are features of some of the new drives.

The modern trolley bus is being used for many services where street cars or gasoline buses were applied previously. Economy of operation and low investment cost insure a widespread use of trolley buses, especially where it is possible to utilize existing power plant, substation, and power distribution facilities. In Chicago, for instance, over fifty-seven miles of line have been equipped for trolley bus operation, and seventy-five buses are in use.

The gas-electric coach, which has hitherto shown its chief advantages in congested urban traffic where frequent and rapid acceleration is necessary, is invading the interurban field.

Attention is called to the expansion of the subway mileage in Philadelphia, New York, and Brooklyn. Plans for a subway in Chicago have been approved.

Rail Fissure Detector

The Sperry device for detecting fissures in track rails has been operated intensively throughout the country with valuable results. Continued use of this device should materially reduce rail failures.

Welding

Electric welding is increasingly used not only in railroad shops (as in other industries), but for building up rails and "special work" at frogs, crossings, etc. Rail bonds for traction and signal purposes are in many instances welded to the head of the rails.

Vertical Transportation

The ever increasing height of buildings necessitates constantly increasing efficiency and speed of elevators. Speeds of 900 ft. per min. are now operated. A recent development to increase space efficiency in high buildings, is the operation of two or more elevators in a single shaft, so synchronized that one elevator may be started and run as "express" for a certain number of floors before the car next below it starts. Needless to say the operation is interlocked by means of limit switches and kindred devices to prevent the cars from coming together.

General

Attention is called to the development of various types of apparatus which apply to transportation as well as to other forms of utilization of electricity as described in various technical committee reports. Included in this category are turbo-generators and other power plant facilities, motors, circuit breakers, insulators, transformers, lightning arresters, cables, relays, substations, etc. Many of these types of apparatus are applicable to transportation, only by accomplishing some more or less important modifications, and the attention of various technical committees has been called to special modifications of this kind.

Attention is called to the work which is being carried on under the auspices of the American Standards Association on Definitions of Electrical Terms (C-42) for which the A. I. E. E. is sponsor. To Subcommittee No. 6 is assigned the field of "Horizontal Transportation." It is hoped that when this very important subject is complete, and published, general use will be made of the definitions and that some confusion which now exists will thus be avoided.

Protective Devices

ANNUAL REPORT OF COMMITTEE ON PROTECTIVE DEVICES*

THE work of the Committee on Protective Devices during the past year was accomplished largely through subcommittees, which are listed below with their chairmen:

Relays, W. W. Edson; Oil Circuit Breakers, Switches and Fuses, L. F. Hickernell; Lightning Arresters, H. K. Sels; Fault Current Limiting Devices, H. B. Wood; Joint Interconnection Subcommittee,† F. C. Hanker.

The activities of the Protective Devices Committee may be divided into the following three classes:

1. Preparation of standards
2. Review of research and development
3. Fostering the preparation and presentation of papers.

General

During the year the work of the committee in cooperation with the National Electric Light Association in the preparation of a supplement to the Relay Handbook was completed.

Revised standards for lightning arresters have been prepared and issued in report form by the Standards Committee.

Progress has been made in the preparation of standards for fuses and revised standards for disconnecting, horn gap and knife switches. It was hoped that the standard for fuses could be sent to the Standards Committee this year, but due to difficulties in obtaining complete agreement as to the subject matter of this standard there has been some delay. These standards should be forwarded to the Standards Committee in the latter part of 1931.

The committee has maintained close contact with research and development relating particularly to lightning protection, high-speed oil circuit breakers, and stability of operation, which greatly facilitated its work in fostering the preparation of suitable papers relating to these subjects.

The work of the committee during the past year has emphasized more than ever the following points. First, the desirability of planning the presentation of papers sufficiently in advance so that they may be grouped for presentation in the most suitable manner. Second, the necessity, if maximum advantage is to be realized from Institute sessions, of having papers available for reading sufficient time in advance of meetings to permit of well considered discussion. The importance of this latter point is so great that every effort should be made to see that it is carried out effectively.

On account of the fact that in a number of cases other technical committees of the Institute have a very definite interest in the application or use of devices coming under the jurisdiction of the Protective Devices Committee, very close coordination of activities is required. This is particularly true in matters relating to interconnection and stability of operation handled at the present time by the joint subcommittee having representatives from the Power Generation and Power Transmission and Distribution Committees, in addition to the Protective Devices Committee. It may be that there will be sufficient important matters which affect a number of committees to warrant selecting some method of handling them that will permit of direct effective action without the complication and delays that are bound to happen in coordinating work with several large committees.

Relays

Report of Subcommittee

Further development of high-voltage transmission and interconnection with rather severe requirements as to stability and continuity of service, have focused attention on the necessity of rapid clearing with extreme precision, and the development of the art of relay protection has advanced as a consequence. Relays have been developed including directional, balanced, and differential relays capable of operating in one-sixtieth of a second.

These are being tried out in service and their operation is being watched with much interest. Apparently, additional work should be done to simplify these relays and their mechanical construction details, so as to insure among other things high-speed operation under all conditions, and to prevent shifting of the balance point. Also, further development will apparently have to be gone ahead with to eliminate certain difficul-

*COMMITTEE ON PROTECTIVE DEVICES:

Raymond Bailey, Chairman,

J. E. Allen,	F. C. Hanker,	A. H. Schirmer,
A. C. Cummins,	E. A. Hester,	H. K. Sels,
H. W. Drake,	L. F. Hickernell,	H. P. Sleeper,
W. S. Edsall,	Dr. M. G. Lloyd,	E. R. Stauffacher,
W. W. Edson,	J. P. McKearin,	H. R. Summerhayes,
L. E. Frost,	H. A. McLaughlin,	E. M. Wood,
E. E. George,	A. M. Rossman,	H. B. Wood.
Herman Halperin,		

†This is a joint subcommittee of the committee on Power Generation, Power Transmission and Distribution and the Protective Devices Committee.

ties in the application of these relays to short line sections or to ground protection.

The most important work of the subcommittee for the year is the completion of the revised edition of the Relay Handbook, in cooperation with the corresponding committee of the N. E. L. A.

The following papers, prepared under the auspices of this subcommittee, have been presented before the Institute:

Relay Developments on Southern California Edison System, E. R. Stauffacher, Southern California Edison Company.

Operating Experience with Reactance Type Distance Relays, E. E. George, the Tennessee Electric Power Company.

Protection of Three-Winding Power Transformers, R. E. Cordray, General Electric Company.

Fundamental Basis of Distance Relaying, W. A. Lewis, Westinghouse Elec. & Mfg. Company.

Oil Circuit Breakers, Switches, and Fuses

Report of Subcommittee

A prominent feature of oil circuit breaker development is the number of large installations of metal-clad switchgear. Among these may be mentioned the installation of 33-kv. oil-filled gear on the system of the Public Service Company of Northern Illinois, the 13-kv. gum-filled gear at the Leaside Substation of the Hydro-Electric Power Commission, and air-filled gear on the system of the Jersey Central Power & Light Company.

Since last year's development of the deion circuit breaker, further results have followed the discovery of this method of arc extinction. With the addition of deion grids, ordinary oil circuit breakers have opened 3,500 amperes at 110,000 volts with 1.5 cycles of arcing; and 3,000 amperes at 200,000 volts with 3.5 cycles of arcing or less. Decreased arcing assures more satisfactory breaker performance, less deterioration of oil and contacts and lower maintenance. The stability of the whole power system is improved, since short circuits are more likely to be cleared before they can affect synchronous machines.

The deion oil-less breaker in the meanwhile has been developed for a greater range of ratings. At one extreme is a one million kva. 23 kv. circuit breaker which has undergone interrupting capacity tests including some shots as high as 800,000 kva. (It will be recalled that among last year's achievements were reported successful interruptions of short circuits in the order of 60,000 kva.) On the other extreme is the breaker (using 2.5-inch plates) which repeatedly interrupted 10,000 amperes at 600 volts alternating current. This small deion breaker shows great promise in a wide field of the moderate and smaller powers; such, perhaps, as industrial service.

Efforts to improve rating standards for oil circuit breakers continue.

Announcements by the manufacturers indicate healthy activity in the development of new forms of circuit interrupters, such as the oil-blast oil-circuit breakers, multiple break and others.

The following papers, prepared under the auspices of this subcommittee, have been presented before the Institute:

The Mechanical Performance of Oil Circuit Breakers, A. C. Schwager, Pacific Electric Mfg. Co.

Outdoor Switching Equipment at Northwest Station, W. F. Sims and C. G. Axell, Commonwealth Edison Co.

Magnitudes and Rates of Rise of Circuit Breaker Recovery Voltages, R. H. Park and W. F. Skeats, General Electric Co.

Trend in Development of Modern Circuit Interrupters, J. B. MacNeill, Westinghouse Elec. & Mfg. Co.

Oil Circuit Breaker Tests—Philo 1930; Aims, Set-Up and Results from a System and Operating Point of View, Philip Sporn and H. P. St. Clair, American Gas & Elec. Co.

The Oil-Blast Circuit Breaker, D. C. Prince and W. F. Skeats, General Electric Co.

Field Tests on Standard and Oil-Blast Explosion Chamber Oil Circuit Breakers, R. M. Spurck and H. E. Strang, General Electric Company.

Lightning Arresters

Report of Subcommittee

The Subcommittee is advised that studies of lightning and the effects of lightning were continued throughout the year by means of field investigations on transmission systems in several widely separated localities. The knowledge of the character and behavior of high-voltage surges originating from lightning on transmission lines was extended by the use of cathode-ray oscillographs at field stations located in Arkansas, Illinois, Michigan, New Jersey, Ohio, Pennsylvania, and West Virginia. In two cases, Michigan and New Jersey, the behavior of waves on transmission lines was studied in detail by the use of both portable cathode-ray oscillographs and impulse generators. Practically a continuous investigation was maintained also of the performance of lightning arresters and many other associated phases of the lightning protection problem. About 3,000 oscillograms were taken which have already proved valuable in the study of problems related to lightning protection.

Better coordination of records in the 1930 lightning investigations has indicated the growing importance of direct strokes. Records obtained on high-voltage lines tend to confirm the thought that overvoltage due to direct strokes are more important than those due to the induced effect from lightning strokes primarily on account of their greater magnitude.

Impulse tests made in the field tend to confirm the conclusion that best protection with lightning arresters is obtained when the arrester is located close to the equipment to be protected and the leads as short as possible with low ground resistance. If the arrester cannot be located close to the equipment and at the

same time retain short leads, keeping the leads short appears to be the more important. Also, the arrester and equipment should be connected to the same ground but if this is not convenient, more attention must be given to the arrester ground to be sure that its resistance is as low as possible.

The highest voltage lightning arresters ever built were recently installed by the Hydro-Electric Power Commission of Ontario. Under emergency conditions of generator overspeed and abnormal line voltage, they will not be damaged by voltages as high as 268,400 volts. Normally, four of the twenty-two arrester units in each phase leg are short circuited by a high speed switch which opens automatically in less than half a second when waterwheel overspeed and overvoltage occurs. This is also the largest arrester installation for voltages over 200,000. One three-phase arrester is installed for the protection of each of four banks of transformers.

The commercial development of the porous block autovalve arrester has made available a new arrester which is considerably smaller and has much better performance characteristics than the earlier autovalve. The arrester is constructed in fewer porcelain-cased units with a totally enclosed gap structure which in the lower voltage sizes results in the complete arrester being housed in a single casing or two casings with gaps and elements separate. The protective action of the arrester is similar to the old one but it has practically no time lag in its operation and a low ratio of discharge voltage to normal voltage. A small and compact form of line arrester has been developed which can be applied to prevent the flashover of insulator strings. A number of installations of these line arresters has been under observation for the past two years in order to gather data on the effectiveness of such protection for transmission line insulators.

With the commercial development of thyrite, a new form of lightning arrester became available. The arrester is constructed in the form of self-contained units, it only being necessary for any application to mount an appropriate number of units one upon another. A gap structure has been provided in each unit so constructed that substantially no time lag occurs in the operation of the gap. This arrangement, coupled with the characteristics of the material, insures an arrester which has practically no time lag in its operation. A number of installations of these arresters has been made, the highest voltage arrester in service being of 230 kv. rating. Another form of thyrite arrester was developed which is incorporated in a string of suspension insulators and used to prevent the flashover of the insulator string for all but the most severe conditions.

A new protective device operating on a deion principle in a small bore tube for use in the prevention of insulator flashover by lightning has been developed in certain voltage ratings.

The revision of the proposed Standards for Lightning Arresters for alternating-current power circuits was completed and accepted by the Committee on Protective Devices for printing in report form. The subcommittee hopes that there will be widespread use of these standards in order that they may be put in final shape for adoption by the Institute. It is expected that development in the art of protection from lightning will probably make it necessary to revise these standards from time to time as additional technical information becomes available.

The work of the subcommittee indicates that the following matters should receive considerable attention in the future: (1) the determination of more representative test surges, (2) the development of tests to determine operating condition of arresters in service, (3) investigation of present operating practise on transmission and distribution systems relative to arrester installation, operation and performance as affecting suitable standards, and (4) the coordination of line and station type arrester application in the field with the activities of other committees interested in the grading of system insulation.

The following papers, prepared under the auspices of this subcommittee, have been presented before the Institute:

An Experimental Lightning Protector for Insulators, J. J. Torok, Westinghouse Elec. & Mfg. Co.

Field Tests on Thyrite Lightning Arresters Using Artificial Lightning of 1,500,000 Volts, K. B. McEachron and E. J. Wade, General Electric Company.

Fault Current Limiting Devices

Report of Subcommittee

The reactor installations made during the year are characterized by high electrical ratings and greater physical size, particularly in bus-sectionalizing applications which seem to be on the increase.

Among the largest ever built in physical size is an application of 4,000-kva., 161-kv. bus sectionalizing reactors giving 10 per cent reactive drop when 120,000 kva. is transferred across the reactor.

Another outstanding installation from the standpoint of physical size consists of three 5,400-kva. oil-immersed reactors on the 110-kv. system of the Pacific Gas & Electric Co.

Noteworthy from the standpoint of electrical rating are eighteen bus-sectionalizing reactors rated 7,340 kva. giving a 16½ per cent reactive drop in a 133,000-kva., 27,600-volt circuit now on order.

Current-limiting reactors of the dry type installed in metal housings and rated 833 kva., 693 volts, 1,200 amperes, 60 cycles, were used to sectionalize a 24,000-volt bus. They introduce 5 per cent reactive drop between the sections when 50,000 kva. are being transferred. The housings are supported on insulators and are connected to a ground bus.

Bus-sectionalizing reactors were in some instances provided with disconnecting devices which automatically break the circuit when the reactor is removed from its operating location.

Representative opinion has been secured on the

desirability of including in the new A. I. E. E. Standard for Fault Current Limiting Devices the material on reactors now in A. I. E. E. Standards No. 13 and also information on grounding transformers, generator neutral reactors, and Petersen coils. As yet no definite decision has been reached.

INTERCONNECTIONS

Report of Joint Subcommittee

The work of the Joint Interconnections Subcommittee has related almost entirely to the preparation of papers. A comprehensive paper on *Present Day Practise in Grounding of System Neutrals* was prepared by the subcommittee and presented at the Pittsburgh District Meeting.

A paper entitled *Impulse Test on Substations*, by Messrs. Brookes, Southgate, Roman, and Whitehead, was presented at the Winter Convention.

The following papers were presented at the Pittsburgh Meeting:

Committee Report on Present Day Grounding Practises, C. A. Powel, Chairman.

Reactance of Transmission Lines with Ground Return, J. E. Clem, General Electric Company.

Power System Voltages and Currents Under Fault Conditions, R. D. Evans and S. H. Wright, Westinghouse Elec. & Mfg. Company.

Simultaneous Faults and Six-Phase Transmission, Edith Clarke, General Electric Company.

Power System Voltages and Currents Under Fault Conditions, R. D. Evans and S. H. Wright, Westinghouse Elec. & Mfg. Co.

Series Resistance Method of Increasing Transient Stability Limit, R. C. Bergvall, Westinghouse Elec. & Mfg. Co.

Research

ANNUAL REPORT OF COMMITTEE ON RESEARCH*

DURING the year the Committee members have reviewed twenty-six papers and recommendations have been made to Headquarters for their disposition. Each paper has been reviewed by three or more members and outside experts. The Committee held one session at the Winter Convention at which eight of the approved papers were presented. Additional papers, obtained through the Committee on Research, are scheduled for the Summer Convention and several papers made available for district meetings. All business was carried on through correspondence as the only Committee meeting scheduled, at the Winter Convention, had to be abandoned because of conflicts.

The following topics are of sufficient importance to be called to the attention of the electrical engineering profession. The subjects reported have all been suggested by the Committee members, special assistance having been given by Messrs. W. G. Cady, V. Karapetoff, H. H. Race, D. W. Roper, T. Spooner, and J. B. Whitehead.

PHYSICS

In the field of physics there has been a number of theoretical and experimental accomplishments of some interest during the past year.

The knowledge of cosmic rays has been advanced somewhat with two schools of thought: certain investigators, as a result of certain experimental evidence, are convinced that cosmic rays are actually high velocity particles. However, Dr. Millikan, from intensity measurement of the cosmic rays in northern latitudes, feels quite certain that they are actually rays, since they are not affected by the earth's magnetic field. Dr. Millikan concludes that the cosmic rays have their origin not in the stars, but in interstellar space and that they are due to the building up of the commoner heavy elements from hydrogen, it being thoroughly established by spectroscopy that hydrogen is widely distributed through space. Several of the more common elements and also helium exists in interstellar space.

After seven years of intensive work, Dr. Paul Heyl of the Bureau of Standards has remeasured the constant of gravitation, or as the newspapers would put it, the weight of the earth. This figure is 6.670×10^{-8} c. g. s. units.

Eddington has developed a theory which makes possible the calculation of the ratio of masses of an electron and proton as well as the sizes of the electron and of the universe.

The generation of very short radio waves is possible by a number of means, among them the Barkhausen tube. This tube is a three electrode tube with suitable voltages applied to the grid and plate and provided with parallel Lecher wires. The frequency is dependent on the speed of the electrons as affected by the voltages

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and spacing of the electrodes and is independent of the external characteristics. Shuster has applied quantum mechanics to the problem of the Barkhausen tube and has calculated correctly the observed frequencies.

As a result of the work of Grondahl it has been known for some years that copper oxide on copper had a photoelectric effect, making possible the generation of electric energy from sunlight. Dr. B. Lange of the Kaiser Wilhelm Institute for silicate investigation has obtained some interesting results with the copper oxide cell. According to newspaper reports he has, with the use of silver selenide, obtained similar results, but of one hundred or more times as much magnitude. However, for the generation of power from sunlight, the development is very far from being commercial owing to the high cost and low output.

Medicine and Physiology

In the realm of medicine and physiology there has been a number of developments of interest to the electrical engineer. The recent paper on "Experiments on High Voltage Tubes," by Tuve, Hafstad, and Dahl of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, describes an X-ray tube, the voltage of which can be as high as 2,000 kilovolts. At 1,300 kilovolts the absorption coefficient, after filtering through one inch of lead is the same as that for the gamma rays from radium in equilibrium measured under the same conditions with the same instrument. This result has been attained by the so-called heat working of the pyrex glass. This high voltage tube should serve as a new tool to the medical profession.

For the treatment of cancer there has been developed by Dr. W. D. Coolidge a 900,000-volt X-ray tube to be installed in the New York Memorial Hospital.

It is well known that fever assists in destroying certain disease germs. It is possible, by the use of high frequency electrostatic fields, to produce artificial fever, thus assisting nature. Considerable success has been obtained by this method during the past year.

Dr. George Sperti of the University of Cincinnati has succeeded in using selected regions in the ultraviolet spectrum for the irradiation of foods; for example, he has been able to create Vitamin D in milk without spoiling the taste.

Dr. H. C. Rentschler has developed a method for measuring ultraviolet radiation by the use of a suitably designed photocell and a condenser. The condenser is charged slowly through the photocell and discharges through a counter at a rate dependent upon the ultraviolet radiation received by the photocell.

Dielectrics

Considerable progress has been made in insulation and dielectric research during the past year. Much work is being done to improve the processing in the manufacture of high-voltage cable insulation and also to detect a faulty impregnated cable before it goes into service. At Johns Hopkins University the value of thorough drying by the use of vacuum and air pressure during impregnation and the use of gas free oils have been studied further. To detect poor insulation, research workers of the University of Illinois are measuring high frequency discharges which constitute internal ionization.

Studies on the oils themselves are under way at the Detroit Edison Company, Cornell University, and the Brooklyn Edison Company, with special emphasis on the life characteristics and products of such oils under electrical stress, particularly ionic and electronic bombardment. At the Detroit Edison Company, it has been found that by bombardment of the oil vapors in a vacuum, the composition of the gas produced varies from one hydrocarbon to another and is quite complex, but consists roughly of 50 per cent hydrogen and 50 per cent unsaturated hydrocarbons. Liquids and wax-like solids are also produced. The solid formed is a duplicate of the compound "X" found in cables which have been in service. The formation of this substance in cables indicates internal corona. Five normal paraffin hydrocarbons of simple chemical structure and of very high purity have been prepared at the Bureau of Standards and studies are being made of their electrical characteristics.

Further studies have been made of polar compounds in liquid dielectrics. The frequency-temperature-loss characteristics have been studied in a number of laboratories with most interesting results. In addition, the polar characteristics of certain commercial insulating liquids are being studied, particularly the change and polar characteristics during service. These fundamental studies should aid in a choice of better insulating oils.

At Johns Hopkins University correlation between d-c. absorption and a-c. dielectric loss has been verified for several oils, dried paper and impregnated paper consisting of the materials previously studied alone. The relatively high d-c. conductivity of oil obtained up to about one second after electrification was found to account for the a-c. losses. The electrical characteristics of the separate and combined materials of impregnated paper insulation have been studied. This is a very important step in the fundamental side of dielectric research.

Another field of investigation which is just getting under way is the use of X-rays to study the molecular structure of dielectrics. The work of Dr. Zwicky at the California Institute of Technology on mosaics and on sodium chloride crystals, and the work in Chicago by Dr. Bennett on the effect of an electric field on the arrangement of paraffin crystals are worthy of notice.

There have been numerous important and interesting engineering developments during the past year.

Lightning Research

As the result of the investigations of natural and artificial lightning carried on at a number of field stations in various parts of the country, it has been pretty definitely established by the use of the cathode ray oscillograph that most outages and damage to transmission lines are the result of direct strokes rather than induced lightning. Two records during 1930 were obtained of crest values of 4,500 and 5,000 kv. The latter value was recorded at a distance of several miles from the stroke. At the place of flashover it is estimated that the potential was at least 10,000 kv. It has been concluded that a lightning stroke to a ground wire, if flashover does not take place, does not result in a surge over the line. By using proper precautions it is believed, as a result of these lightning investigations, that it will be possible to build transmission lines which will be practically immune from lightning.

There have been developed and placed on the market during the year, two new types of lightning arresters, namely the thyrite arrester by the General Electric Company and the new porous block autovalve arrester by the Westinghouse Elec. & Mfg. Co. These arresters have characteristics which are considerably superior to their predecessors.

The commercial development and application of new types of discharge tubes have been very active recently. It seems evident that these devices are going to occupy a very large place in the control and conversion of power.

Radio

In connection with radio there have been developed and put into commercial operation, 200 kw. transmitting tubes for broadcast stations.

Mercury-glass three-phase rectifiers have been developed to supply plate current for these high power radio tubes. These rectifiers are rated at 10,000 volts and 30 amperes. Additional grid-controlled gaseous discharge tubes, namely, the Westinghouse grid glow tubes and the General Electric thyratrons which are similar in their characteristics, have been developed during the year, the larger sizes being able to handle 75 amperes at voltages up to 1,000 or even 2,000. A grid energy of ½ watt or less is required.

Many new applications for grid glow tubes have been made recently. Among them is the theater light dimmer system which is controlled by very small rheostats which regulate the voltage applied to the grids of the tubes. These tubes supply rectified alternating current to choke coils which are saturated by the pulsating current, thus changing the inductance and controlling the lights. The small control wires can be led to any desired location, thus concentrating the control and simplifying the operation of the system. There are no moving parts and contacts, except for the small control rheostats. A very great advantage of this type of control is that the whole lighting program for the evening may be preset.

Miscellaneous

A new stroboscope called a stroboglow has been developed, which illuminates a moving object for a period of only 3/10 of a microsecond or less. This interval is so short that an object moving at seven miles a minute appears to be perfectly stationary with no appreciable blur. No moving parts are necessary and no connection between the stroboglow and the moving object is required. The instrument is calibrated for frequency and may be used to determine the speed of rotation of the illuminated object.

A very small tube rectifier has been developed, rated at 3/10 of an ampere and 5,000 volts. This rectifier is 4½ in. long and 1¼ in. in diameter. It can be operated satisfactorily up to 10,000 volts and under special conditions, has been carried as high as 30,000 volts. These tubes are particularly suited for airplane radio transmitters.

A new oscilloscope with a linear time axis has been developed which employs a new type of cathode ray tube for its essential element. This oscilloscope has the advantage over previous types in that it has a larger field and the illumination is very much greater, making it possible to observe recurrent phenomena in a well lighted room. Non-recurrent phenomena lasting for a few microseconds, can also be observed readily for qualitative results. For recurrent phenomena the cathode beam may be synchronized so that the image appears stationary.

An automatic traffic control system has been developed and put into experimental use on main highways, using a beam of light crossing the side streets. When a car or other vehicle approaches the main highway on the side street, the beam is intercepted, thus causing a photocell to act giving the minor street the green light.

There has been developed in Germany another application of the light sensitive devices for the purpose of stopping railroad trains. Light from the headlight of the locomotive is reflected from a mirror on the semaphore and returns to photocells on the locomotive, which when illuminated operate the automatic stop mechanism.

There has recently come into general use in this country the electric photo-flash lamp which was developed in Germany and is used as a substitute for flash-light powder. The bulb contains a quantity of aluminum foil in an atmosphere of oxygen. A small filament, when heated electrically, causes the aluminum foil and oxygen to combine with an intense illumination. The elimination of noise and smoke is greatly appreciated by the average audience.

Studies and applications of piezo electric quartz crystals have been continued at Wesleyan University. By means of the cathode ray oscillograph, the rate of

dying away of the oscillations of these crystal resonators has been studied. It has been found that a 600-kilocycle crystal started vibrating and left to itself, makes 60,000 vibrations before its amplitude falls to 1 per cent of its initial value. Various types of mountings for the crystals as well as the effect of the shape, cut and material of the crystal itself are being studied. A determination of the viscosity of quartz as a function of frequency is yielded by the above measurements. The coefficient of viscosity or quartz is approximately five at 600 kilocycles as contrasted with 500 for aluminum at 60 kilocycles and with values of the order of 10^8 ordinarily quoted for the low-frequency viscosities of metals.

A very accurate clock developed by the Bell Telephone Laboratories was exhibited at Cleveland last December, which is unique in that it is controlled electrically by a spherical quartz crystal.

The Stevens Institute of Technology reports the development of a clock which is automatically corrected by the standard radio time signals.

The limitations and advantages of commutation and current collection in hydrogen have been determined by laboratory and commercial experiments. In general, in the hydrogen atmosphere there results a lower contact drop. Satisfactory operation and long life are obtained if sparking is kept low. If appreciable sparking is present the humidity must be kept low.

The application of the helical groove to slip rings and commutators has been developed and applied commercially. Under severe conditions of commutation and current collection this apparently reduces brush wear and improves the electrical operation by reducing the formation of local hot spots; also better distribution of current between parallel brushes results.

A sample of commercial hipernik (a 50 per cent nickel-iron alloy) has been obtained having a maximum permeability of 167,000. Test samples from other castings have given as high as 13,000 for initial permeability and upwards of 400,000 for maximum.

Work during the past year on the fundamental nature of arcs and their extinction has given a greater insight into the problem of circuit interruption and is having a very definite effect on the design of circuit breakers.

There has been developed a non-destructive magnetic weld test meter for use with butt welds, which shows some promise commercially. For a given type of weld and a definite kind of steel, comparative results on welds are quite reliable.

At the Naval Research Laboratories interesting work has been done using the radiographic method for detecting imperfections in large steel forgings. Ordinary X-rays can penetrate only three or four inches of steel, but by the use of radium it has been possible to obtain photographs through twelve inches of steel. The radium has the advantage that it can readily be transported to the piece to be inspected and requires no complicated auxiliary equipment. If thick pieces of steel are to be photographed, however, either a long time must be used or a considerable quantity of radium or radium emanation must be available.